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COMMUTING, CO_2 AND THE LOCATION OF OFFICES

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COMMUTING, CO_2 AND THE LOCATION OF OFFICES

Abstract

This paper investigates the extent to which office activity contributes to travel-related CO_2 emission. Using 'end-user' figures[1], travel accounts for 32% of UK CO_2 emission (Commission for Integrated Transport, 2007) and commuting and business travel accounts for a fifth of transport-related CO_2 emissions, equating to 6.4% of total UK emissions (Building Research Establishment, 2000). Figures from the Department for Transport (2006) report that 70% of commuting trips were made by car, accounting for 73% of all commuting miles travelled. In assessing the environmental performance of an office building, the paper questions whether commuting and business travel-related CO_2 emission is being properly assessed. For example, are office buildings in locations that are easily accessible by public transport being sufficiently rewarded? The *de facto* method for assessing the environmental performance of office buildings in the UK is the Building Research Establishment's Environmental Assessment Method (BREEAM). Using data for Bristol, this paper examines firstly whether BREEAM places sufficient weight on travel-related CO_2 emission in comparison with building operation-related CO_2 emission, and secondly whether the methodology for assigning credits for travel-related CO_2 emission efficiency is capable of discerning intra-urban differences in location such as city centre and out-of-town. The results show that, despite CO_2 emission per worker from building operation and travel being comparable, there is a substantial difference in

[1] End-user figures include an estimated share of upstream emissions from power stations and refineries allocated back to the sectors using the electricity or fuel (sometimes referred to as 'well to wheel')

the credit-weighting allocated to each. Under the current version of BREEAM for offices, only a maximum of 4% of the available credits can be awarded for ensuring the office location is environmentally sustainable. The results also show that all locations within the established city centre of Bristol will receive maximum BREEAM credits. Given the parameters of the test there is little to distinguish one city centre location from another and out of town only one office location receives any credits. It would appear from these results that the assessment method is not able to discern subtle differences in the sustainability of office locations.

1. Introduction

According to Pout *et al* (2002), in 2000, commercial, public sector and industrial buildings accounted for 17% of total UK delivered energy consumption and 19% of carbon emission. The equivalent figures for transport are 35% and 32% respectively, approximately one third of total UK energy consumption and CO_2 emission. Commuting / business travel accounts for a fifth of this figure. More recent figures report that transport is responsible for 38.6% of final user energy consumption, a figure that can be contrasted with 19.3% in 1970 (Department for Business, Enterprise and Regulatory Reform, 2008). Furthermore, between 1990 and 2005, while total UK CO_2 emission fell by 6%, transport emissions rose by 11%. According to the Commission for Integrated Transport (2007), using figures from the Office for National Statistics, the energy used directly by households through cooking, heating and using their own vehicles, and indirectly by the generation of electricity, through the use of public transport, taxis and aircraft and from households' final demand for goods and services (which include emissions embedded in imports of goods and services), amounts to around 85% of all UK GHG emissions, and transport accounts for 18% of these emissions (11% private vehicles, 5% aviation, 2% public transport). "The trend towards centralisation of services, distribution and retail provision, often at edge of town developments, …, have all contributed towards increasing demands for transport" (CfIT, 2007). These developments are almost entirely car-dependent and road transport accounts for 93% of transport emissions by source (excluding the UK's share of international aviation and shipping). We use a vast amount of energy driving between home and work. Figures from the Department for Transport

(2006) report that 70% of commuting trips were made by car, accounting for 73% of all commuting distance travelled.

Given the service-based nature of the UK economy, it would seem sensible to ask to what extent office activity is contributing to travel-related CO_2 emission. Office activity generates travel as a result of workers commuting between home and workplace and customers/clients and suppliers visiting the premises. The frequency and length of trips and the mode of transport used will depend on:

- The requirement for
    - Physical presence of workforce
    - Face-to-face contact with clients
- The location of the office in relation[2] to the location of:
    - The workforce
    - The market
    - Complementary business activities and the agglomeration benefits this offers
- Availability and cost[3] of transport modes[4]

In assessing the environmental performance of an office building, is commuting and business travel-related CO_2 emission being properly assessed? There may be an *a priori*

[2] Relative location means the topology (proximity, connectivity and adjacency) of land uses
[3] Each mode has a mix of economic, social and environmental costs and differ in terms of the extent to which these costs are externalised by the firm
[4] Communications networks such as land-lines and cell networks might be regarded as substitutes for physical transport networks

expectation that offices in certain locations (the city centre for example) are associated with lower emissions than other (perhaps edge or out-of-town) locations because of a greater use of public transport. As far as the monitoring of environmental performance is concerned, are office buildings in locations that are easily accessible by public transport being sufficiently rewarded?

The *de facto* method for assessing the environmental performance of office buildings in the UK is the Building Research Establishment's Environmental Assessment Method (BREEAM). BREEAM assesses a number of environmental characteristics including transport-related CO_2 emission. The method is employed on a building-by-building basis yet, as far as office-related travel is concerned, more aggregated office locations or areas might prove to be a more interesting focus. Using data for Bristol, this paper investigates firstly whether BREEAM places sufficient weight on travel-related CO_2 emission in comparison with building operation-related CO_2 emission, and secondly whether the methodology for assigning credits for travel-related CO_2 emission efficiency is capable of discerning intra-urban differences in office locations such as city centre and out-of-town.

2. Literature review

Transport growth began in earnest in the early 20th century and fuelled urban expansion and industrial mobility (Hall, 2002). In 1951 25% of households had access to a car. In 1969 it was 59% (Department of Transport, 2007a). "Growth in car travel further fuelled the growth of urban areas, the spread of residential areas and the movement of industry,

commerce and retail activities to urban periphery locations" (Foresight Sustainable Energy Management and the Built Environment Project, 2008). Over the past half century widespread use of the car as a means of transport for office workers has freed households and businesses from the need to locate close to public transport nodes such as railway stations. Instead they have been able to decentralise to suburban, edge- and to out-of-town locations where land is cheaper and development is usually quicker and cheaper (as a result of fewer constraints relating to ownership, planning and previous uses). Developers, purchasing cheap land, building cheaply and letting at rents comparable to nearby urban locations, were able to reap increased profit at lower risk. Business occupiers, when deciding to locate in edge- and out-of-town locations, have been able to externalise some of the transport-related costs associated with a city centre location. Furthermore, homeowners, faced with considerable house price inflation, have located at increasing distances from workplaces because travel costs have not inflated at the same rate. In effect, rising housing costs have been traded off against lowering travel costs at an increasing rate, thus extending the distances people are prepared to commute. The unintended costs of these development trends are environmental (in the form of local pollution and global climate change) and social (in the form of congestion, traffic accidents and the undermining of local communities).

These trends are borne out in travel data collected by the Government. The distances people are now prepared to travel have shown a marked increase, as shown in figure 1. The average distance people travel annually has increased by nearly 60 per cent since 1972/73 from around 4,500 miles to about 7,133 miles in 2006 (Department for

Transport, 2006 and 2007b). This is the combined effect of an increase in average trip lengths of nearly 50 per cent and an increase in the number of trips made per person per year of 8 per cent. Commuting/business trips accounted for 29 per cent of this figure (2,073 miles) and 78 per cent of this commuting/business travel is by car (either as driver or passenger). This has major implications for environmental sustainability of office space due to the high levels of CO_2 emitted as a result of car-based commuting in comparison to public transport.

But do some office locations generate more commuting/business travel than others and do certain office locations generate more car-based commuting/business travel than others? Titheridge and Hall (2006) reported the findings of Cervero (1988) who found that office decentralisation in North America led to longer journey distances and greater use of private vehicles, although these findings were contested (see Gordon *et al*, 1991 for example). In the Netherlands Konings *et al* (1996) found that developments in existing city limits attracted a greater proportion of public transport commuting than urban extension or rural developments. In Canada the IBI Group (1990) found significant variation in public transport patronage depending on whether the urban form was decentralised (26%), compact (35%) or nodal (29%). In the UK Titheridge and Hall (2006) found that the creation of new growth centres in South East England led to increased car use as the centres provide less opportunities for access by rail.

Census interaction data record people's usual workplace and the usual mode of transport to that workplace. The data do not take account of periods when people may not be

travelling because they are on holiday, off sick, working at home[5] for part of the week or attending meetings away fro the workplace. The data are a proxy for actual travel flows and tend to over-estimate activity at centres of employment. The 2001 Census Special Workplace Statistics (Level 2) (Office for National Statistics) report journey-to-work flows within and between wards. The data are derived from questions on the census form relating to place of usual residence and the place of work for the respondent's main job. The data have been derived from the 100% sample and include imputed households. Where workplace locations were unknown, these were also imputed. Examining this data set for office locations in Bristol, the origins were taken to be all wards in the South West (1,091 wards), South East (1,499 wards), West Midlands (761 wards) and Wales (881 wards) Government Office Regions, totalling 4,232 wards. The destinations were the wards in which the offices are located (14 wards), as shown in table 1.

A filter was applied that removed any origin ward from which there were less than ten journeys to the destination wards. In the census data mode of travel is classified as underground, train, car driver, car passenger, taxi, walk, bike, motorbike, bus, other or home-based. In order to link these modes to the modal classification used by the National Atmospheric Emissions Inventory, walking and cycling were combined (because neither emits CO_2), car driver and taxi have been combined and train and underground travel have been combined. 'Work at home and 'Other' were removed. The remaining modes stayed the same. Table 2 reports the results.

[5] Home-working may reduce transport usage but increase domestic energy use and reduce the energy efficiency of existing workplaces.

There is no distinction between workers employed in office, retail, factory, or other environment. This may help explain the low proportion of rail-based commuting to and from the city centre. The figure of 2% would be expected to be significantly higher if the data related to office workers only. The high proportion of car-based commuting to out-of-town business parks is evident: Aztec West, Almondsbury, Parkway, Brabazon and Bristol Business Park are all located between seven and ten miles to the north of Bristol city centre.

Case study research shows that location in the city centre or out-of-town is significant in terms of travel mode (Department for Transport, 2005). Orange plc has 2,200 staff located at sites on the Aztec West and Almondsbury business parks eight miles to the north of Bristol city centre. Both parks have poor public transport penetration; one public bus service serves Almondsbury Business Park and two serve Aztec West. In 2001, five years after introducing a travel plan, the proportion of staff commuting to these office locations by car was 86%, a proportion broadly in line with the 79% of staff who commute to the nearby Frenchay campus of the University of the West of England[6]. In the same year 750 staff were relocated to Temple Point in Bristol city centre, 100 metres from the mainline railway station and 23 public bus services. Only 31% of staff commute to this office location by car. As Orange stated "[t]he experience of Orange is particularly dramatic in demonstrating the locational advantages of a town centre" (DfT, 2005). But these figures are not unique. In 2000/1 Bristol City Council collected travel data from companies situated at the nearby Temple Quay business park in the city centre and these

[6] According to figures from UWE's travel planner (April 2008).

are shown in table 3. The figures suggest that Orange's performance is broadly comparable with other organisations in the locality that are involved in travel planning.

3. Method

Given the level of car-based commuting and the apparent significant difference between city centre and out-of-town commuting behaviour, this paper has two objectives:

1) To investigate whether BREEAM places sufficient weight on commuting-related CO_2 emission in comparison with building operation-related CO_2 emission
2) To determine whether the methodology for assigning credits for commuting-related CO_2 emission efficiency is capable of discerning intra-urban differences in the location of workplaces

The study focuses on office space in buildings of 10,000 square feet or more that were constructed over the last 50 years in the metropolitan office market of Bristol. Property consultants King Sturge regularly publish details on city centre and out of town buildings of 10,000 square feet or more that have been built since 1956 and are currently used as office space. The city centre sample contains 196 buildings that were constructed over the 52-year time period and that are still in use as office space. Out of town there are seven locations in which 32 business parks that have been developed since 1981. Table 4 provides a breakdown of the gross floor-space of these buildings and figure 2 shows their locations.

In the UK, under BREEAM, credits are awarded for office occupiers that adopt measures to mitigate travel-related CO_2 emission. The number of credits awarded and the way in which they are assessed has changed substantially over the past few years. Table 5 compares the number of credits and weight allocated to each criterion in the 2006 and 2008 versions of BREEAM.

In the latest revision to the assessment method the weight assigned to transport-related environmental issues was reduced from 17 credits (21% of the total number of credits available) to 10 credits (8% of the total number available). But even within the transport section, not all of the credits relate to the location of the office. In BREEAM 2006 it was 12 out of the 17 credits but in BREEAM 2008 it was only 4 out of the 10 available. This means that in 2008 only 3% of total BREEAM credits are available for location-dependent transport features (compared to 15% in 2006). Given the amount of CO_2 emitted as a result of commuting/business travel, this might be regarded as rather low.

Moreover, a very important change was made to the way in which location-dependent transport-related CO_2 emissions were assessed when the 2008 version of BREEAM superseded the 2006 version. In the 2006 version of BREEAM Offices, credits were awarded for offices that had:

a) Access to public transport (up to 2 credits)

b) Low CO_2 emissions resulting from commuting and business travel (up to 10 credits)
c) Cyclist facilities (up to 3 credits)
d) Carried out a travel survey (1 credit)
e) Implemented a travel plan (1 credit)

Of these, only access to public transport and travel-related CO_2 emissions are dependent upon the location of the office building. The others are designed to encourage alternative means of transport rather than measure their CO_2 emission.

a) Access to public transport

One credit is gained if the distance from the building entrance to a public transport node is less than 500 metres and there is a service at least every 15 minutes to a local urban centre between 08:00 and 10:00 and 17:00 and 19:00 Monday to Friday. A second credit is gained if there is a service at least every 30 minutes between 08:00 and 19:00 Monday to Friday to a major transport node serving local and regional infrastructure systems.

b) Commuting and business travel

The following formula is used to estimate the amount (measured in kilograms) of CO_2 emissions emitted per person per annum for each transport mode:

$$\left(N \times D^{L} \times AY_{r}\right) \times AVCO_{2} \qquad [1]$$

Where:

- N is the number of occupants travelling by each mode
- D^L is the distance travelled by mode per journey for the location in kilometres
- AY_r is the average number of journeys made by each person per annum to and from work
- $AVCO_2$ is the average $kgCO_2$ emitted per person per kilometre by mode of travel

Per occupant CO_2 emission between 1,200 and 1,300 kilograms per annum attained 1 credit and an additional credit was awarded for each 100 kilogram reduction up to a maximum of 10 credits for emission of less than 400 kilograms per person per annum[7].

In the summer of 2008 a new version of BREEAM Offices was launched and there were significant changes to the number of transport-related credits available and the way in which they were assessed:

a) Access to the public transport network (up to 3 credits)

[7] Under BREEAM 2006 the way in which credits are awarded for commuting and business travel behaviour changed several times. In early versions 0.76 credits were awarded if there was good access to public transport for commuting with a further 0.76 credits for business travel. Further credits were available based on the location of the office building as follows; a rural location (0 credits), on the edge of town (1.28 credits), in a small town (2.56 credits), in a city or town centre (3.85 credits), in a central urban location (5.23 credits) or close to a major transport node (6.42 credits). In 2007 these location-based credits were revised and subsequently replaced with a commuting-related CO_2 calculator. Per occupant emission between 1,200 and 1,300 kilograms per annum attained 0.64 credits and an additional 0.64 credits were awarded for each 100 kilogram reduction to a maximum of 6.4 credits for emission of less than 400 kilograms per person per annum. In 2008 the credit intervals changed to that stated in the main text. While such revisions reflect new thinking and data, the result is a lack of consistency over time.

b) Access to local amenities (1 credit)

c) Cyclist facilities (up to 2 credits)

d) Site layout that ensures pedestrian and cyclist safety (1 credit)

e) Travel plan (1 credit)

f) Restricted parking (up to 2 credits)

Only access to public transport and local amenities are location-dependent.

a) Access to public transport

An *Accessibility Index* for each building is calculated using Transport for London's *Public Transport Accessibility* (PTAL) method (Transport for London, 2006). The model takes account of the following factors:

- Walk access times between office buildings and public transport access points are based on Ordnance Survey's Centre Alignment of Roads (OSCAR) data set. Only bus stops within a radius of 650 metres and train stations within a radius of 1,000 metres of each building are included in the index calculation for a building. The distance (in metres) is divided by 80 (assumed distance walked in one minute at 4.8 km/hr) in order to express walk access time in minutes. So walk access time is computed as follows:

Walk time (mins) = Distance (metres) / 80 (metres per minute) [2]

- A measure of service frequency is incorporated by calculating the average time between when a passenger arrives at a public transport access point and the arrival of the service. Services that operate from more than one mode in the catchment area (delineated by the radii mentioned above) for the office are considered only once, at the node closest to the building, but different routes from the same node are considered as separate entities. Most routes are bi-directional but only the direction with the highest frequency is considered in the calculation. Office hours are assumed to be between 08:00 to 19:00, i.e. 11 hours (660 minutes), and the number of services on each route are tallied over this time period. Waiting time is based on the assumption that the traveller arrives at the access point, on average, mid-way between services:

  *Waiting time (mins) = 0.5 * (660 / number of services)* [3]

  Additional waiting time is incorporated to reflect service reliability, dependent upon mode of transport available, as follows

  Buses = 2 mins

  Trains = 0.75 mins

The method does not consider speed or utility of the services, crowding or ease of interchange. Nor does it take account of what origin or destination opportunities are

served by the public transport services or where occupiers are likely to live or want to travel to.

The above factors are converted to an Equivalent Doorstep Frequency (EDF) for each route available at the access point:

$$EDF = 30 / (walk\ time + waiting\ time) \quad [4]$$

The accessibility index for all routes on a particular mode of transport is calculated as

$$AI_{mode} = EDF_{max} + (0.5 \times all\_other\_EDFs) \quad [5]$$

Halving the EDFs for all but the main route compensates for the fact the routes often run in parallel for some distance and frequency of destinations are likely to be less than that suggested by the number of routes included in the calculation. Finally, the accessibility index for an office building is the sum of index values for each mode:

$$AI_{office} = \sum (AI_{mode1} + AI_{mode2} + AI_{mode3} \cdots AI_{moden}) \quad [6]$$

Table 6 shows the descriptions assigned to ranges of accessibility index scores using the PTAL methodology and compares these to the credits awarded by BREEAM. Attaining an index score of 8 or more is rewarded with the maximum three BREEAM credits but the same score is described as ‘poor’ under the PTAL method.

b) Access to local amenities

If the office building is located within 500 metres of a grocery store and/or food outlet, post box and cash machine, one credit is awarded.

4. Results

As stated above the objectives of this study were to use the Bristol data and the BREEAM assessment method to investigate two issues: firstly, whether environmental performance of office space in the UK places sufficient weight on travel-related CO_2 emission in relation to CO_2 emission resulting from occupation of the office building itself; and secondly, building on the findings of the literature review in section two, whether the methodology for assigning credits for travel-related CO_2 emission efficiency differentiates sufficiently between city centre and edge/out-of-town locations.

4.1 Weighting

Research by McAllister and Cyril Sweett (2007) estimated annual energy consumption from the operation / occupation (heating, cooling, ventilating, lighting and powering) of different types of new and existing office buildings. The results from this research can be applied to the office stock in Bristol. The energy consumption figures were converted to CO_2 emission equivalents using the conversion factors for gas and electricity published

by the Carbon Trust (2008). These figures, which estimate CO_2 emission per square metre, were expressed as a per occupant metric by assuming that one office worker occupies ten square metres of net internal floor area. Net internal area is defined as gross internal area less common areas and ancillary spaces, which approximates to 80% of gross floor area (Carbon Trust, 2003). The results, classified by type and age of space, are shown in table 7 and are based on the assumption that the office space is 100% occupied, although it would be a simple calculation to adjust the figures to take into account a vacancy rate. These annual emissions per occupant can be converted into an overall average figure for the Bristol office stock by weighting the emissions figures for each of the office specifications and age categories by the proportion of floor-space in each (van de Wetering and Wyatt, 2008). This produces a weighted average of 1,647 kg of CO_2 per worker per annum for office space in the Bristol city-region as a whole. When office space is classified as either city centre or out of town the emissions figures are 1,821 and 1,173 kg of CO_2 per worker per annum respectively. The significant difference is because the majority of office floor-space is located in the city centre and the widespread use of air-conditioning in city centre offices, as illustrated in table 4.

It is possible to estimate a similar metric for CO_2 emission as a result of commuting to and from office workplaces in Bristol. Table 8 shows the distances travelled per person per year on commuting/business, according to the UK Government statistics (Department for Transport, 2006: Table 7.2). If it is assumed that the ratios of miles travelled on each transport mode are typical for Bristol commuters, these figures can be linked to data from the National Atmospheric Emissions Inventory which reports the amount of CO_2 emitted

by each mode. The result is an estimate of average CO_2 emission per person per year for commuting/business travel weighted by distance travelled by each mode. The weighted average is 273kg of CO_2 per worker per annum; a figure that is 17% of the building-related CO_2 emissions attributable to each worker in the Bristol city-region as a whole. Given the time spent in the office (typically seven to eight hours per day) relative to the time spent commuting (approximately one hour per day[8]) it is interesting to note that, when the results are normalised for time, more CO_2 is emitted by occupants travelling to and from workplaces than is emitted whilst working from these premises.

Given the relative significance of the amount of CO_2 emitted commuting to and from in comparison to that emitted as a result of building operation then one would expect the weighting that BREEAM allocates to these two sources of CO_2 emission to reflect this. Looking at the weighting BREEAM allocates to energy and transport criteria: in 2006 28% of the available credits were energy-related and 21% transport-related. In other words the ratio of transport to energy credits was 75%; an over-allocation. However, in 2008 these weightings changed substantially, to 21% and 8% respectively. Furthermore, of the transport credits available, 71% in 2006 and only 40% in 2008 are dependent on location. This means that in 2008 only 3% of total BREEAM credits are available for choosing a location that seeks to reduce transport-related CO_2 emission. This is a substantial drop from the 15% that was available in the 2006 version of BREEAM. This 3% contrasts with the 15% of total credits available for reduction of CO_2 emissions associated with operational energy consumption, which increased from 12% in the 2006 version.

[8] 2006 national Travel Survey, Table 4.2, Office for National Statistics and the Department for Transport

4.2 Location differentiation

Given the significant difference between the weightings and methods of assessment for travel-related CO_2 emission in the 2006 and 2008 versions of BREEAM, both were investigated using the Bristol data.

BREEAM 2006

Access to public transport

Using a geographical information system (GIS) a 500 metre buffer was constructed around the Bristol road network and railway stations as illustrated in figure 3. 90% of office space in the Bristol city region lies within this buffer. The table in figure 3 shows the results when the time and frequency of the bus services are taken into account. Clearly the city centre performs much better than out of town. Due to the hub and spoke arrangement of bus and rail transit systems, all city centre office space meets the BREEAM public transport requirements whereas only 11% of out-of-town space meets the peak (commuting) requirement and 77% meets the daytime (business travel) requirement. The 77% figure may flatter to deceive because it is due in large part to a daytime bus service running through the large Aztec West and Almondsbury Business Parks and if the journey time (approximately one hour to the city centre) were considered it might explain why so few business commuters and visitors travel by bus. In fact,

according to government statistics, only 5% of commuters travel by bus on average in the south west of England (Department for Transport, 2008: Table 1.8).

Under this assessment criterion all city centre offices would score the maximum of two credits. Out-of-town offices are poorly served by public transport for commuting but over three quarters of floor-space is served by a daytime service. Overall, because the majority of premises are in the centre, a high proportion of total office floor-space gains the maximum two credits.

Commuting and business travel

Essentially, under BREEAM 2006, the aim was to estimate the amount of CO_2 each occupant emits each year as a result of travelling to and from the office. Credits were awarded along a falling scale from less that 1,300 $kgCO_2$ per worker per annum (1 credit) to less that 400 $kgCO_2$/worker/year (10 credits). When estimating emissions for the existing stock in Bristol as a whole (rather than each individual building) necessary inputs for the calculations can be obtained using the published statistical and case study data referred to in the literature review.

Distance travelled by each mode requires two inputs: the proportion of workers that travel by each mode and the distance that they travel. Rather than compute distance travelled per annum by multiplying journey length by number of journeys (as in the BREEAM formula), it is possible to obtain national and regional statistics on distance travelled per

person per year (classified by purpose and mode) from the Department for Transport (2006 and 2007b). The figures for commuting/business purpose are shown in table 9 (rows 1 and 2). In order to differentiate city centre from out-of-town office locations these statistics have been supplemented with data obtained from the census, from Bristol City Council and travel surveys undertaken by Orange plc in relation to city centre (rows 3-8) and out-of-town (rows 9-17). No account is taken for home-working.

Using figures from the Department for Transport that report the average distance travelled by each person each year on commuting and business travel (row 18), together with figures from the National Atmospheric Emissions Inventory that report the CO_2 emission of each mode (row 19), it is possible to calculate the CO_2 that a person would emit each year for each mode. Given that annual CO_2 emission of the average car driver is 391kg, this would still be enough to score a maximum of 10 credits under the BREEAM 2006 assessment method. If the CO_2 emissions are weighted by the proportions of commuters using each mode, we can estimate CO_2 emission per person per year for the different spatial extents. Starting at the national level, the weighted average is 272kg CO_2 per person per annum. Every permutation is below the minimum BREEAM assessment threshold of 400 kg CO_2 per worker per year, so all locations and all travel modes (including single-occupancy driving) score the maximum of 10 credits.

BREEAM 2008

Access to public transport

Office locations in Bristol city centre are well served by bus and rail services. Figure 4 shows 650 metre buffers around the main bus stops and railway stations serving the centre. The number of services that stop at each of the bus stops is indicated on the map. The frequency of each of the services during the hours stipulated in BREEAM 2008 (08:00 – 19:00) was ascertained. Then, given the large number of bus stops in the city centre, rather than calculate an accessibility index score for each of the office locations (red squares), it was assumed that each office was located at half the maximum buffer distance (325 metres) from the nearest stop. The accessibility index for each office location can then be calculated. The calculations are shown in appendix 1 and it can be seen that all office buildings in the centre (apart from six that lie outside the buffer[9]) receive an accessibility index score of at least 8 and so receive the maximum of three BREEAM credits. This is analysis focuses on the main bus stops; there are many intermediate bus stops on the routes throughout the city which would raise the accessibility index scores. From appendix 2 it can be seen that none of the out of town office parks score any credits for public transport accessibility apart from Brabazon Business Park in Filton because it is located on a primary route into Bristol that is well served by buses.

[9] The two office buildings near Bristol Temple Meads railway station would be included if the route network used to calculate accessibility included pedestrian routes rather than roads only.

The approach investigates the BREEAM 2008 criteria for public transport by looking through the other end of the telescope – looking at the configuration of the public transport network first and then examining how well it serves office locations rather than looking at a specific office location and examining how well the public transport network serves it. What it demonstrates is that all locations within the established city centre of Bristol will receive maximum BREEAM credits. Given the parameters of the test there is little to distinguish one city centre location from another.

Access to local amenities

One credit is awarded if an office building is located within 500 metres of a grocery shop and/or food outlet, post box or cash machine. For the purposes of this analysis it is assumed that petrol filling stations are regarded as food outlets. Using the Rating List from the Valuation Office Agency it is possible to extract business premises in the Bristol sub-region (defined as the BS postcode district) that match the following descriptions:

Petrol filling stations	315
Supermarkets	102
Banks	370
ATMs	162
Post offices	118
Foodstores	77
TOTAL	1,144

This was a fairly restrictive interpretation of the BREEAM criteria. So, as a second test, all retail premises were identified within the Bristol sub-region distributed amongst the local authority districts as follows:

Bristol City	4,983
North Somerset	1,561
South Gloucestershire	1,477
Bath & North East Somerset	1,837
TOTAL	9,858

These premises were geographically referenced at the unit postcode level. Polygons were then delineated that circumscribed a contour around each city centre office and out-of-town office location that joined places that were 500 metres away along the road network. Any polygon that did not contain at least one of the abovementioned amenities would not receive a BREEAM credit under this criterion.

The results showed that all city centre offices were within 500 metres of these amenities. Of the 315,000 square metres of out-of-town office space 214,000 square metres (76%) were not within 500 metres of an amenity. This was approximately 18% of the total office space in the Bristol sub-region and the majority is located on the north fringe of Bristol on the Aztec West, Almondsbury, Emerson's Green, Vantage and Parkway North business parks and half of Bristol Business Park is also more than 500 metres away from

an amenity (the shop on the nearby university campus). Two business parks on the outskirts of Portishead also failed to receive a credit; these were Portis Fields and Eden Office Park.

5. Conclusions

There are mandatory regulations and discretionary initiatives that are requiring and encouraging office occupiers to consider the energy efficiency and carbon emissions of the real estate that they operate from. In the UK mandatory regulations include Energy Performance Certificates and Display Energy Certificates that were introduced as a result of the EU Energy Performance of Buildings Directive. Further regulation will take the form of carbon trading. Voluntary initiatives tend to take the form of environmental performance assessment tools such as the Code for Sustainable Buildings and BREEAM. However, under the current version of BREEAM for offices, only a maximum of 4% of the available credits can be awarded for ensuring the office location is environmentally sustainable.

Using the 2006 model parameters the results show that all city centre locations and nearly all out-of-town locations receive maximum BREEAM credits. Using the 2008 method there is little to distinguish one city centre location from another and, out-of-town, only one office location received any credits. It would appear from these results that the 2008 version of the assessment method is not able to discern intra-urban differences in the travel-related CO_2 emissions of office locations.

The extent to which a property generates and relies upon carbon-based transport is significant to its environmental performance. The results show that there is a substantial difference in the CO_2 emitted by commuters to city centre and out of town office locations. The more sustainable solution is clearly proximity to public transport node(s). As Orange stated "[t]he experience of Orange is particularly dramatic in demonstrating the locational advantages of a town centre" (Department for Transport, 2005) and the Department for Transport concludes in that report: "[o]rganisations in out-of-town locations are likely to have more difficulty in achieving low levels of car use. The example of Orange … shows how much easier it is to encourage a change in travel habits at a central location" (Department for Transport, 2005). It is important to consider environmental performance beyond simply the operation of the building itself. In the future, increasing objections to road-building, out-of-town development and unrestrained vehicle use may influence the location and use of buildings. Locations that generate increased road traffic may fall out of favour. Haig (1926) used the phrase 'friction of space' to describe the way occupiers seek to minimise economic transport costs when choosing a location. A similar notion might be used to describe how occupiers may seek minimise the environmental and social costs of work-related travel.

Acknowledgement

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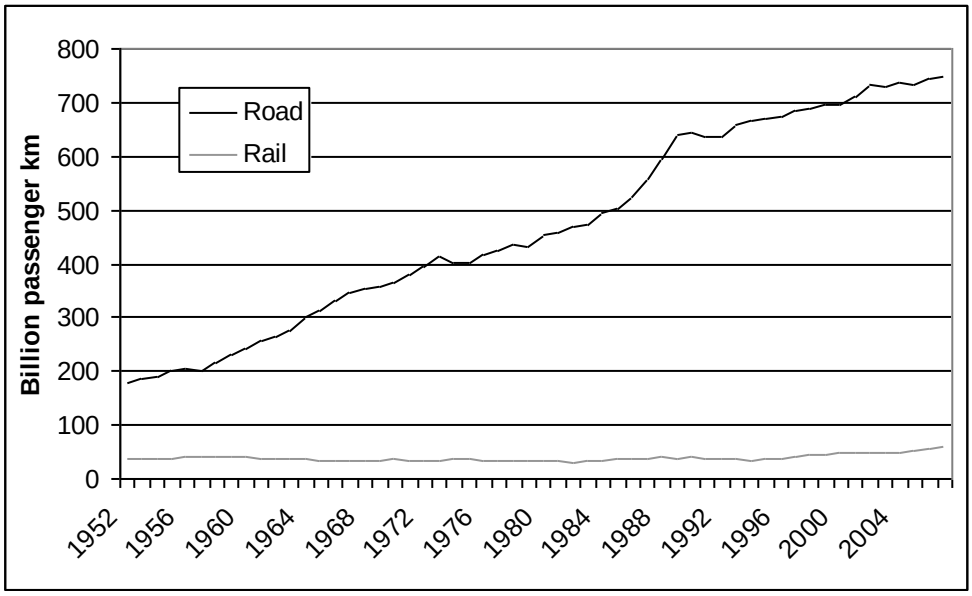

Figure 1: Passenger transport by road and rail (1952-2007)

[Source: Department for Transport (2008), using data from Table 1.1]

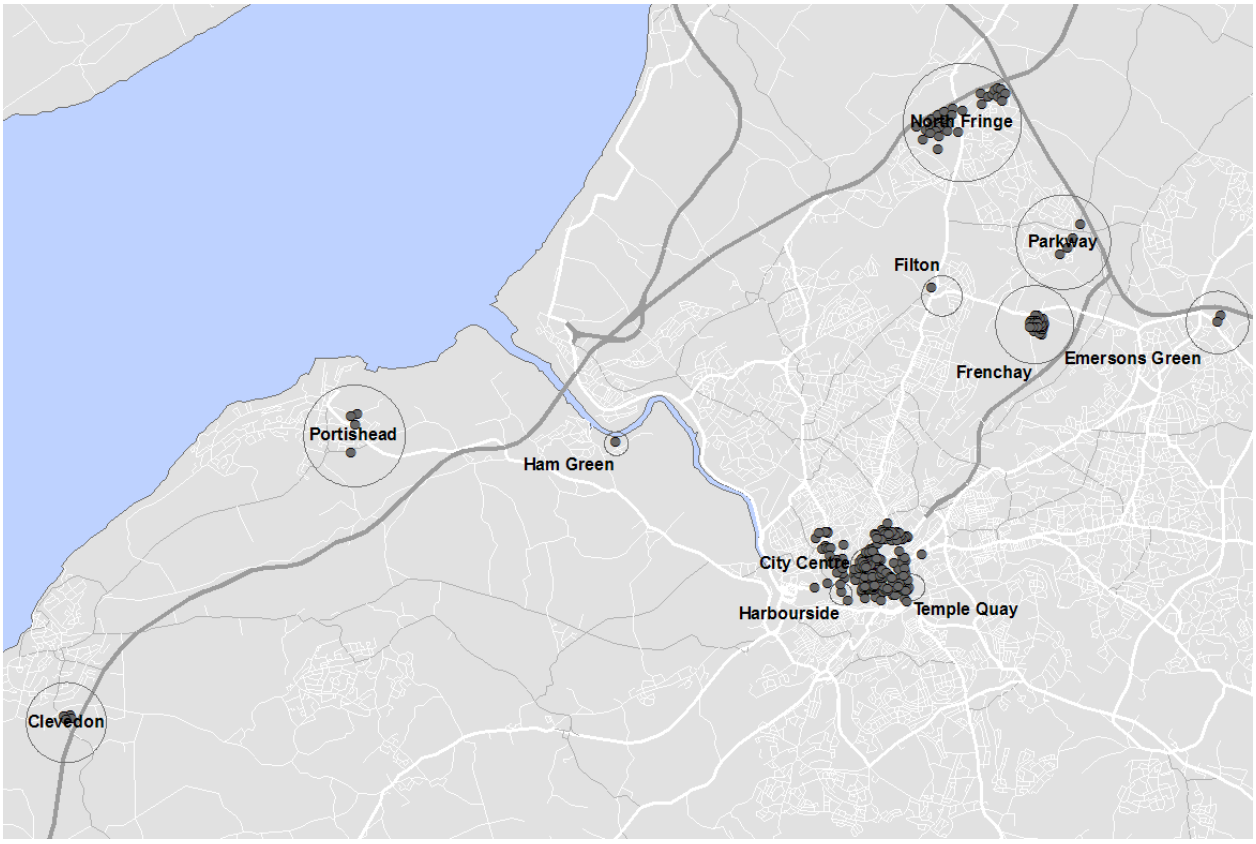

Figure 2: Main city centre and out-of-town office locations in the Bristol sub-region

(Ordnance Survey gazetteer and location data Crown Copyright)

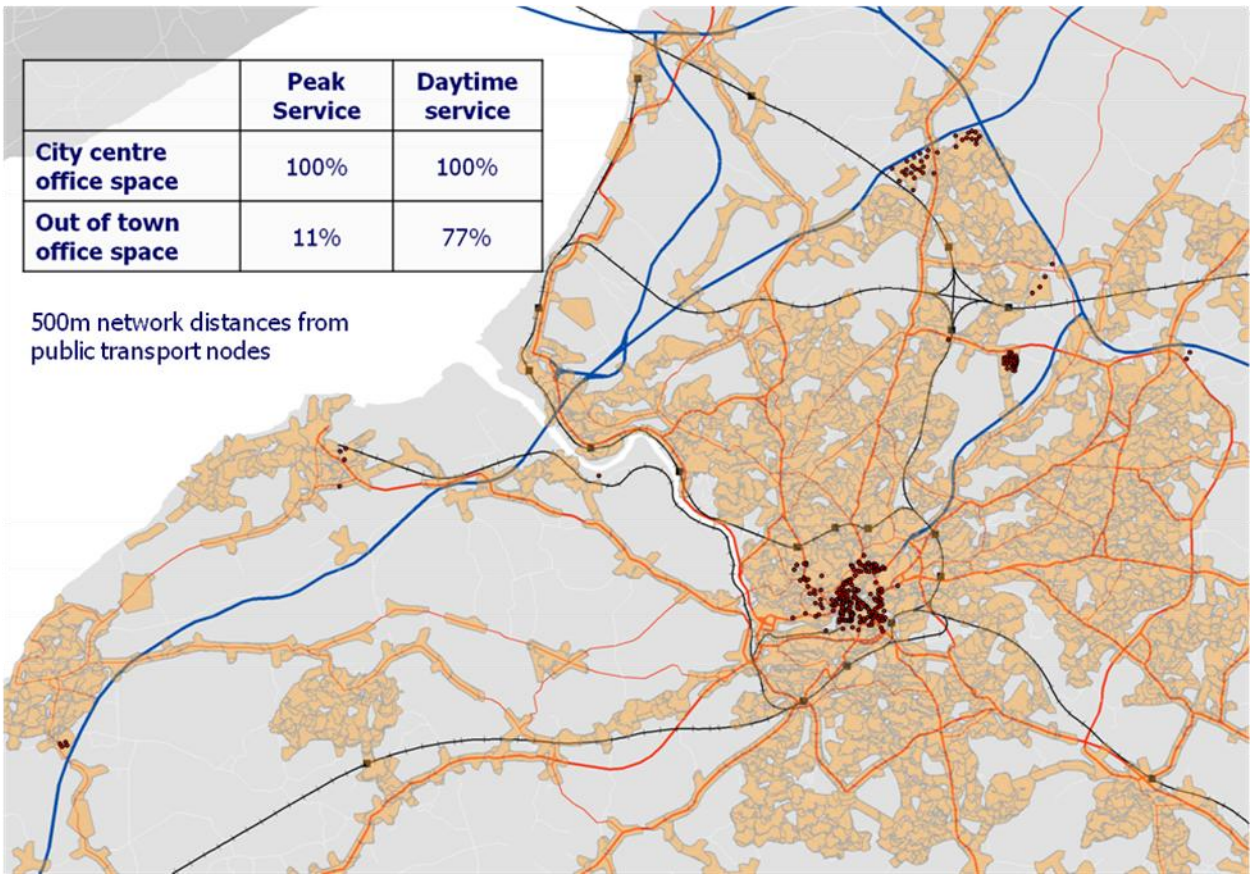

Figure 3: Proximity of offices to public transport nodes in Bristol

(Ordnance Survey gazetteer and location data Crown Copyright)

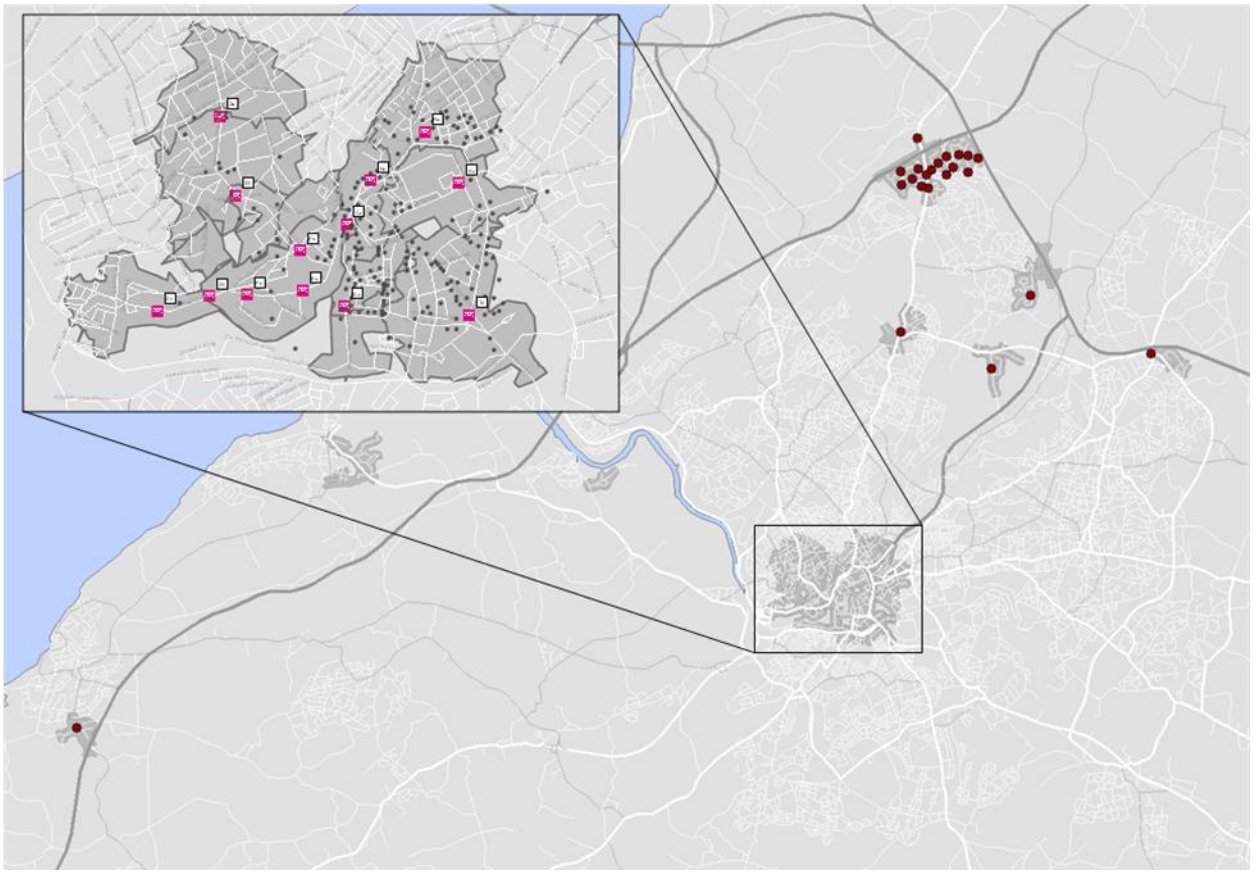

Figure 4: 650 metre buffer around railway stations and main bus stops in Bristol city centre

(Ordnance Survey gazetteer and location data Crown Copyright)

Table 1: Wards in which offices are located

OFFICE LOCATION	*WARD (Ward Code)*
City centre	Lawrence Hill (00HBPM), Cabot (00HBNU), Clifton (00HBNW), Clifton East (00HBNX) and Ashley (00HBNM)
Out-of-town:	
• Clevedon	Yatton (00HCQC)
• Portishead	Portishead East (00HCPL)
• Ham Green	Pill (00HCPH)
• Aztec West	Patchway (00HDPN)
• Almondsbury	Bradley Stoke Bowland (00HDNX)
• Parkway	Bradley Stoke Baileys Court (00HDNW) and Stoke Gifford (00HDPU)
• Brabazon	Filton (00HDPE)
• Bristol Busness Park	Winterbourne (00HDPZ)

Table 2: Proportion of commuters travelling from origin wards to destination wards, classified by mode of travel

Office location	Car driver (inc taxi)	Car passenger	Train	Motor-cycle	Walk / bike	Bus
Clevedon	57%	4%	1%	1%	15%	2%
Portishead	63%	5%	0%	1%	11%	1%
Ham Green	55%	4%	0%	2%	18%	2%
Aztec West	76%	6%	0%	1%	9%	4%
Almondsbury	77%	5%	0%	1%	6%	4%
Parkway	66%	6%	2%	1%	9%	7%
Brabazon	71%	6%	1%	4%	12%	4%
Bristol Business Park	70%	6%	4%	2%	10%	5%
City centre	47%	6%	2%	2%	19%	21%

Source: 2001 Census: Special Workplace Statistics (Ward Level)

Table 3: Proportion of commuters travelling to specific offices in Bristol (2000/1), classified by mode of travel

Office *location* and occupier	Mode of travel					
	Car driver (inc taxi)	Car passenger	Train	Motorcycle	Walk/bike	Bus
Out-of-town						
Orange (Aztec West & Almondsbury)	79%	7%	-	2%	6%	7%
City centre						
Orange	27%	4%	16%	8%	22%	7%
Andersons	23%	-	29%	-	25%	23%
Bristol & West	28%	8%	13%	2%	15%	36%
DAS	29%	21%	9%	2%	14%	25%
City centre average	27%	11%	17%	4%	19%	27%

Source: Bristol City Council

Table 4: Gross floor-space (m^2) of office space in Bristol (2008)

	Naturally ventilated cellular	Naturally ventilated open-plan	Air-conditioned standard	Air-conditioned prestige	*Sub-Total*	*Total*
City Centre: Under 10 years		1,765	14,320	178,368	*194,454*	
City Centre: 10+ years	32,270	195,219	391,336	67,875	*686,700*	
CITY CENTRE						*881,153*
Out-of-town: Under 10 years		43,193	91,760		*134,953*	
Out-of-town: 10+ years		100,619	73,659	5,853	*180,131*	
OUT-OF-TOWN						*315,084*
TOTAL						*1,196,238*

Table 5: BREEAM Offices

	2006 version		2008 version	
Criterion	**Credits**	**%**	**Credits**	**%**
Management	4	5	10	12
Health and Wellbeing	15	18	14	15
Energy	23	28	21	19
Transport	17	21	10	8
Water	9	11	6	6
Materials	3	4	12	12.5
Waste	-	-	7	7.5
Land Use & Ecology	0	0	10	10
Pollution	11	13	12	10
TOTAL	**82**	**100**	**102**	**100**

Table 6: PTAL Index and BREEAM credits

PTAL			BREEAM	
Range of Index	Description		Range of Index	BREEAM Credits
0.01-5.00	Very poor		>= 2.00	1
5.01-10.00	Poor		>= 4.00	2
10.01-15.00	Moderate		>= 8.00	3
15.01-20.00	Good			
20.01-25.00	Very good			
25.01+	Excellent			

Table 7: Typical annual CO_2 emission of office buildings

	Specification							
	Naturally Ventilated Cellular		Naturally Ventilated Open Plan		Air-conditioned Standard		Air-conditioned Prestige	
	New	Exist	New	Exist	New	Exist	New	Exist
$kgCO_2/m^2$ of floor area	32.67	56.36	43.41	75.16	84.70	153.20	206.45	230.32
$kgCO_2$/occupant[1]	408.38	704.50	542.63	939.44	1058.75	1915.00	2580.63	2979.00
Proportion of Bristol stock (in terms of gross floorspace)	0%	3%	4%	26%	9%	39%	14%	5%

Source: McAllister & Cyril Sweett (2007) and Carbon Trust (2008)

[1] $kgCO_2/m^2$ of floor area divided by 0.8 (ratio between gross and net internal floor areas) and multiplied by 10 (m^2 net internal area per occupant)

Table 8: Commuting / business travel-related CO_2 emission

Mode	Kilometres travelled per person per year on commuting/business	CO2 emission (kg/km/person)	CO2 emission (kg/person) weighted by distance travelled by each mode
Walk / Bike	51 (1%)	0	0
Car driver	2285 (69%)	0.1710 (single)	267.68
Car passenger	304 (9%)	0.0855 (share)	2.37
Motorcycle	26 (1%)	0.0872	0.01
Other private	31 (1%)	-	-
Local bus	109 (3%)	0.0762	0.27
Rail / underground	439 (13%)	0.0486 (train)	2.81
Other public	90 (3%)	-	-
All modes	*3336 (100%)*		*273.16*

Source: Department for Transport, National Atmospheric Emissions Inventory

Table 9: CO_2 emissions by mode of travel and by location

Row	Office location	Proportion using each mode						Kg CO_2 per person per year weighted by mode	Source
		Car driver (inc taxi)	Car Pass'r	train	Motor-cycle	Walk/ bike	Bus		
1	*England*	69%	-	8%	1%	14%	7%	272	DfT (2008) Transport Stats GB
2	*South-West*	76%	-	2%	1%	15%	5%	298	
	Bristol Centre								
3	• Orange	27%	4%	16%	8%	22%	7%	111	Bristol City Council and Orange plc
4	• Andersons	23%	-	29%	-	25%	23%	98	
5	• Bristol & West	28%	8%	13%	2%	15%	36%	117	
6	• DAS	29%	21%	9%	2%	14%	25%	123	
7	Average[1]	27%	11%	17%	4%	19%	27%[2]	114	
8	City centre	47%	6%	2%	2%	19%	21%	187	2001 Census
	Bristol Out-of-town								
9	• Orange	79%	7%	-	2%	6%	7%	311	Orange plc
10	• Clevedon	57%	4%	1%	1%	15%	2%	224	2001 Census

11	• Portishead	63%	5%	0%	1%	11%	1%	248	
12	• Ham Green	55%	4%	0%	2%	18%	2%	216	
13	• Aztec West	76%	6%	0%	1%	9%	4%	299	
14	• Almondsbury	77%	5%	0%	1%	6%	4%	303	
15	• Parkway	66%	6%	2%	1%	9%	7%	260	
16	• Brabazon	71%	6%	1%	4%	12%	4%	280	
17	• BBP	70%	6%	4%	2%	10%	5%	276	
18	Distance travelled each year on commuting / business travel (km)	2,285	304	439	26	51	109		DfT (2008) Transport Stats GB
19	CO2 emission (kg/km)	0.1710	0.0855	0.0486	0.0872	0	0.0762		National Atmospheric Emissions Inventory
20	Annual CO2 emission by mode (kg)	391	26	21	2	0	8		

[1] Averages of figs for four offices in Temple Quay area of Bristol so do not add up to 100%

[2] Includes P&R so journeys may include car as part of multi-mode trips

Appendix 1: City centre accessibility index calculations

Stop	Service	Dist	Walk Time	No. Services	Freq	SWT	Reliability Factor	Total Access Time	Equivalent Doorstep Frequency	Access Index [1]	Total
Zz	1	325	4.06	41	16	8.05	0.75	12.86	2.33	1.17	
	8	325	4.06	33	20	10.00	0.75	14.81	2.03	1.01	
	9	325	4.06	30	22	11.00	0.75	15.81	1.90	0.95	
	40	325	4.06	37	18	8.92	0.75	13.73	2.18	1.09	
	41	325	4.06	31	21	10.65	0.75	15.46	1.94	0.97	
	54	325	4.06	53	12	6.23	0.75	11.04	2.72	**2.72**	
	624	325	4.06	3	220	110.00	0.75	114.81	0.26	0.13	
	X14	325	4.06	9	73	36.67	0.75	41.48	0.72	0.36	
											8.40
Dt	1	325	4.06	41	16	8.05	0.75	12.86	2.33	1.17	
	8	325	4.06	33	20	10.00	0.75	14.81	2.03	1.01	
	9	325	4.06	30	22	11.00	0.75	15.81	1.90	0.95	
	40	325	4.06	37	18	8.92	0.75	13.73	2.18	1.09	
	41	325	4.06	31	21	10.65	0.75	15.46	1.94	0.97	
	54	325	4.06	53	12	6.23	0.75	11.04	2.72	**2.72**	
	330	325	4.06	44	15	7.50	0.75	12.31	2.44	1.22	
	624	325	4.06	3	220	110.00	0.75	114.81	0.26	0.13	
	x14	325	4.06	9	73	36.67	0.75	41.48	0.72	0.36	
											9.62
Ps	1	325	4.06	41	16	8.05	0.75	12.86	2.33	1.17	
	8	325	4.06	33	20	10.00	0.75	14.81	2.03	1.01	
	9	325	4.06	30	22	11.00	0.75	15.81	1.90	0.95	
	40	325	4.06	37	18	8.92	0.75	13.73	2.18	1.09	
	41	325	4.06	31	21	10.65	0.75	15.46	1.94	0.97	
	54	325	4.06	53	12	6.23	0.75	11.04	2.72	**2.72**	
	330	325	4.06	44	15	7.50	0.75	12.31	2.44	1.22	
	624	325	4.06	3	220	110.00	0.75	114.81	0.26	0.13	
											9.26
Pq	350	325	4.06	8	83	41.25	0.75	46.06	0.65	0.33	
	351	325	4.06	3	220	110.00	0.75	114.81	0.26	0.13	
	354	325	4.06	21	31	15.71	0.75	20.53	1.46	0.73	
	357	325	4.06	27	24	12.22	0.75	17.03	1.76	0.88	
	358	325	4.06	11	60	30.00	0.75	34.81	0.86	0.43	
	359	325	4.06	11	60	30.00	0.75	34.81	0.86	0.43	
	362	325	4.06	11	60	30.00	0.75	34.81	0.86	0.43	
	363	325	4.06	0							
	364	325	4.06	12	55	27.50	0.75	32.31	0.93	0.46	
	500	325	4.06	31	21	10.65	0.75	15.46	1.94	0.97	
	902	325	4.06	44	15	7.50	0.75	12.31	2.44	**2.44**	
	X1	325	4.06	21	31	15.71	0.75	20.53	1.46	0.73	
	X7	325	4.06	11	60	30	0.75	34.81	0.86	0.43	
											8.39
Pp	350	325	4.06	8	83	41.25	0.75	46.06	0.65	0.33	
	351	325	4.06	3	220	110.00	0.75	114.81	0.26	0.13	
	354	325	4.06	21	31	15.71	0.75	20.53	1.46	0.73	
	357	325	4.06	27	24	12.22	0.75	17.03	1.76	0.88	
	358	325	4.06	11	60	30.00	0.75	34.81	0.86	0.43	
	359	325	4.06	11	60	30.00	0.75	34.81	0.86	0.43	

	362	325	4.06	11	60	30.00	0.75	34.81	0.86	0.43	
	364	325	4.06	12	55	27.50	0.75	32.31	0.93	0.46	
	500	325	4.06	31	21	10.65	0.75	15.46	1.94	0.97	
	902	325	4.06	44	15	7.50	0.75	12.31	2.44	**2.44**	
	X1	325	4.06	21	31	15.71	0.75	20.53	1.46	0.73	
	X7	325	4.06	11	60	30	0.75	34.81	0.86	0.43	
											8.39
Zo	350	325	4.06	8	83	41.25	0.75	46.06	0.65	0.33	
	351	325	4.06	3	220	110.00	0.75	114.81	0.26	0.13	
	354	325	4.06	21	31	15.71	0.75	20.53	1.46	0.73	
	357	325	4.06	27	24	12.22	0.75	17.03	1.76	0.88	
	358	325	4.06	11	60	30.00	0.75	34.81	0.86	0.43	
	359	325	4.06	11	60	30.00	0.75	34.81	0.86	0.43	
	362	325	4.06	11	60	30.00	0.75	34.81	0.86	0.43	
	364	325	4.06	12	55	27.50	0.75	32.31	0.93	0.46	
	500	325	4.06	31	21	10.65	0.75	15.46	1.94	0.97	
	902	325	4.06	44	15	7.50	0.75	12.31	2.44	**2.44**	
	X1	325	4.06	21	31	15.71	0.75	20.53	1.46	0.73	
	X7	325	4.06	11	60	30	0.75	34.81	0.86	0.43	
	586	325	4.06	11	60	30	0.75	34.81	0.86	0.43	
	587	325	4.06	11	60	30	0.75	34.81	0.86	0.43	
											9.25
Zn	350	325	4.06	8	83	41.25	0.75	46.06	0.65	0.33	
	351	325	4.06	3	220	110.00	0.75	114.81	0.26	0.13	
	354	325	4.06	21	31	15.71	0.75	20.53	1.46	0.73	
	357	325	4.06	27	24	12.22	0.75	17.03	1.76	0.88	
	358	325	4.06	11	60	30.00	0.75	34.81	0.86	0.43	
	359	325	4.06	11	60	30.00	0.75	34.81	0.86	0.43	
	362	325	4.06	11	60	30.00	0.75	34.81	0.86	0.43	
	364	325	4.06	12	55	27.50	0.75	32.31	0.93	0.46	
	500	325	4.06	31	21	10.65	0.75	15.46	1.94	0.97	
	902	325	4.06	44	15	7.50	0.75	12.31	2.44	**2.44**	
	X1	325	4.06	21	31	15.71	0.75	20.53	1.46	0.73	
	X7	325	4.06	11	60	30	0.75	34.81	0.86	0.43	
	586	325	4.06	11	60	30	0.75	34.81	0.86	0.43	
	587	325	4.06	11	60	30	0.75	34.81	0.86	0.43	
											9.25
Bz	20	325	4.06	35	19	9.429	0.75	14.24	2.11	1.05	
	21	325	4.06	12	55	27.5	0.75	32.31	0.93	0.46	
	24	325	4.06	29	23	11.38	0.75	16.19	1.85	0.93	
	52	325	4.06	30	22	11	0.75	15.81	1.90	0.95	
	75	325	4.06	64	10	5.156	0.75	9.97	3.01	**3.01**	
	76	325	4.06	31	21	10.65	0.75	15.46	1.94	0.97	
	77	325	4.06	31	21	10.65	0.75	15.46	1.94	0.97	
	90	325	4.06	53	12	6.226	0.75	11.04	2.72	1.36	
	121	325	4.06	7	94	47.14	0.75	51.96	0.58	0.29	
											9.99
Cz[2[	Number of services			57						>	8.00
Hz	Number of services			24						>	8.00
Rz	Number of services			47						>	8.00
Sz	Number of services			27						>	8.00
Tz	Number of services			31						>	8.00

[1] The emboldened index values are the main routes so the equivalent doorstep frequencies are not halved.

[2] Stops from Cz onwards are the major bus stops in the centre of Bristol and are served by numerous routes. Consequently individual services are not listed as resulting access values are all in excess of 8.00.

Appendix 2: Out-of-town accessibility index calculations

	Bus Route(s)	Ave Dist	Walk Time	No. Services	Freq	Std Wait Time	Reliability Factor	Total Access Time	Equiv. Doorstep Freq.	Access Index
Clevedon	660	256	3.20	5	132	66.00	2.00	71.20	0.42	0.42
Parkway	72	278	3.48	7	94	47.14	2.00	52.62	0.57	0.57
Emerson's Green	342	609	7.61	11	60	30.00	2.00	39.61	0.76	0.76
Filton	71/72	160	2.00	11	60	30.00	2.00	34.00	0.88	
	75/75a	82	1.03	62	11	5.32	2.00	8.35	3.59	
	309/310	82	1.03	23	29	14.35	2.00	17.37	1.73	
	517/518	82	1.03	47	14	7.02	2.00	10.05	2.99	
										6.39
Ham Green	358/359	600	7.50	29	23	11.38	2.00	20.88	1.44	1.44
Portishead 1	357	308	4.47	11	60	30.00	2.00	36.47	0.82	0.82
Portishead 2	358/9	99	1.24	11	60	30.00	2.00	33.24	0.90	
	X25/6	99	1.24	13	51	25.38	2.00	28.62	1.05	
										1.50
Bristol	312	616	7.70	8	83	41.25	2.00	50.95	0.59	
Business	318	616	7.70	10	66	33.00	2.00	42.70	0.70	
Park	319	616	7.70	11	60	30.00	2.00	39.70	0.76	
	517/8	616	7.70	22	30	15.00	2.00	24.70	1.21	
	581	616	7.70	12	55	27.50	2.00	37.20	0.81	
										2.64
Aztec West / Almondsbury	73	484	6.05	4	165	82.50	2.00	90.55	0.33	0.33