Urban transport and social inequities in neighbourhoods near Underground stations in Greater London

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ABSTRACT

Social equity, and the contribution that transport planning can make to social equity, are increasingly attracting the attention of transport planners and researchers. This perhaps reflects the heightened levels of social inequity in cities and the concern over differential access to transport and participation in activities. This paper considers these issues by applying the Capabilities Approach to transport, in order to examine an individual's opportunities to travel and engage in activities (capabilities) and their actual day to day travel and engagement in activities (functionings). London is selected as a case study using analysis from three Underground stations on the Jubilee Line Extension. The findings show that there are statistically significant differences in terms of capabilities and functionings across the socio-demographic characteristics of individuals, and also across different neighbourhoods in London. It is argued that unless local residents' potential travel opportunities and actual activities, and the gaps between them, are better understood and responded to, the problem of transport-related social inequity is likely to persist in London. Therefore, we suggest that the findings from this research, including the multi-dimensional social indicators and understanding of the barriers to accessibility, could be used alongside existing approaches such as accessibility planning.

1. Introduction

When considering social equity[1] issues in a Western country, it is useful to refer back to Plato (427-347BC), a Greek philosopher and founder of the Academy in Athens. In 'The Republic', he discusses social justice, explaining that: "each ruling group sets down laws for its own advantage; … their own advantage is just for the ruled … everywhere is the same thing, the advantage of the stronger." (Bloom 1968, 16). Plato proposes that society should therefore try to move beyond this, and strive for the 'just polis' (just city). The difficulty, of course, is that social equity is a nebulous and multi-faceted concept, a relative term, and heavily dependent on the context within which it is used. It may be clear that the current situation demands attention to remedy inequity, but not obvious how this may compare to other contexts, nor what the key indicators of equity might be, what level of equity should be achieved, and how this might be done in relation to transport.

        In this study, we consider these issues by examining the opportunities available

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[1] 'Social equity' and 'social justice' are often employed interchangeably in studies, but we interpret social equity to mean having fair access to opportunities, livelihood, education, and resources, and social justice as a fair and just relationship between the individual and society, encompassing the distribution of wealth, opportunities and social privilege (Mella Lira and Hickman 2017). The paper therefore focuses on social equity issues and how these might be related to transport.

to individuals in different neighbourhoods, how these are related to actual activities, and how both of these differ by population group. The Capabilities Approach (CA) (Sen 1985, 1999, 2009) is used as the theoretical framework for the analysis. London is used as a case study, specifically selected residents in the vicinity of the Jubilee Line Extension (JLE) in East London. This paper makes a contribution to existing research by applying the CA concept to the field of transport, as well as suggesting multi-dimensional social indicators that might be used to assess transport-related social equity. The aim of the paper is to examine how transport and social equity differ for individuals across various socio-demographic characteristics and different neighbourhoods, even though they might have very similar levels of accessibility to the local public transport infrastructure (i.e. the Underground). Hence, we gain an understanding of how transport-related social equity differs relative to opportunity, across population group and by space. The paper is organised as follows: section 2 outlines the previous literature and suggests how CA might be applied to the transport context; section 3 describes the case study, data collection and methodology; section 4 provides the modelling results and commentary; and section 5 offers further discussion and draws conclusions.

2. The previous literature – using the CA in the transport context

The CA was developed by Sen (1985, 1999, 2009) initially examining poverty and inequality issues in India. Sen (1973) argued that the focus on economic growth in development studies did not allow for a meaningful understanding of how societies and individuals may develop most effectively. Levels of income could not be used to evaluate wider issues, such as well-being and multidimensional inequality (Sen 1985, 1998). Therefore, Sen argued that the freedom that people have to lead a valuable life, based on their capabilities to engage in a wide range of activities, should also be considered. However, CA has proved problematic in application, as there was no clear specification of the capabilities that could be used to assess inequality. Nussbaum (2003, 2011) observed that Sen did not provide a definitive list of capabilities that could be used to assess social inequity, hence she developed a list of central human capabilities with which to analyse an individual's capabilities.

In the field of transport planning, analysis related to social equity has developed over the last 20 years, focusing mainly on qualitative analysis and empirical case studies (Arranz-Lopez et al. 2019; Bocarejo and Oviedo 2012; Cuthill et al. 2019; Lucas 2004; Lucas 2012; SEU 2003; Vasconcellos 2001; Zhao and Li 2016) and including recent attempts to strengthen the theoretical debate (Beyazit 2011; Feitelson 2002; Geurs et al. 2009; Gössling 2016; Hickman et al. 2017; Litman 2017; Lucas 2012; Martens 2012; Pereira et al. 2017). However, social equity measures that have been implemented within the field of transport planning remain inadequate and in some cases ambiguous (Di Ciommo and Shiftan 2017). Social equity has not been clearly translated into a clear objective for policy-makers to aim towards (Manaugh et al. 2015). Although a few studies have provided evidence relating to transport-related social equity, there are still many areas to develop within research. For example, first, many studies have explored the relationship between transport and social exclusion due to a lack of adequate public

transport provision, and they have generally used accessibility[2] as a key indicator with which to assess transport infrastructure projects (e.g. use of Accession modelling and Public Transport Accessibility Levels, PTAL). However, it is argued that relatively similar levels of accessibility to the nearest transport infrastructure could still lead to social inequity, as an individual's potential travel opportunities may be unachievable for a variety of reasons. Second, an approach based on using a single indicator might not be sufficient to fully assess the degree of social progress achieved (Stiglitz et al. 2009).

Table 1 gives a summary of key literature in relation to transport and the CA. Use of the CA has been gradually gaining ground within transport and social equity research, and is an innovative approach with which to evaluate whether people's expectations can be fulfilled by existing transport systems, whether their capabilities could be improved, and whether everyone could gain equal benefits from transport systems (Beyazit 2011, Hickman et al. 2017). Furthermore, Beyazit (2011) suggests that the CA could be integrated with the existing methods to assess social equity within the transport context. Martens (2017) concludes that the use of capabilities and functionings is difficult to translate to the transport domain, because the key argument of the CA is that: "[d]oing x and choosing to do x are, in general, not equivalent" (Sen 1988, p.292). In other words, the CA draws a distinction between 'capabilities' and 'functionings'. In the transport domain, functionings is taken to mean "actual activity participation ('what a person has succeeded in doing'), while accessibility captures a person's capabilities ('the range of doings a person could achieve')" (Martens 2017, 500, Hickman et al., 2017)). Capabilities can, of course, differ between individuals, hence the use of accessibility to represent capability is not quite accurate. Only a few scholars have tried to apply the CA empirically. For example, Hanael and Berechman (2016) used the CA as a threshold with which to assess whether people's minimum transport service provision requirements, such as affordability, reliability, efficiency, convenience, and safety, were being met or not in the case of King County, Washington, in relation to its transport policy. Ryan et al. (2015) applied the CA to analyse the relationship between the perceived possibility and actual use of public transport as mobility elements and mobility resources in Stockholm. However, it is acknowledged that evidence relating to transport equity remains scarce due to the limited number of empirical studies that have used the CA in the transport context.

In order to measure transport-related social equity by using the CA, the key concepts to use are capabilities (an individual's opportunities to participate in activities) and functionings (the activities which they are currently performing) (see Cao and Hickman 2018, 2019; Hickman et al. 2017; Ryan et al. 2015). Table 2 develops Nussbaum's (2000, 2003, 2011) list of central human capabilities and applies them within the transport field using a set of multidimensional indicators (Hickman et al. 2017), covering issues of life, bodily health, bodily integrity and emotions, etc. These include issues related to the journey experience, activity participation and emotion, which are not usually covered in assessments of the social impact of transport

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[2] Accessibility is defined as the level of access to the nearest part of the transport infrastructure, i.e. public transport accessibility level (PTAL) (see TfL 2015).

interventions, but that we argue are also important to consider in transport analysis

Table 1. Summary of key literature in relation to transport and the capabilities approach (Source: authors).

Types of Research	Key Scholars	Use of CA	Key Findings
Theoretical study	Beyazit (2011)	• Uses the CA to uncover gaps in social justice thought in relation to transport; • Uses CA as an evaluation tool to assess transport projects; • Applies strengths, weaknesses, opportunities and threats (SWOT) analysis to discuss the potential for using the CA in transport studies.	• Proposes use of CA in the field of transport to develop individual human capabilities, taking needs, values and freedoms into account; • Shows the potential challenges of using CA and measuring capabilities in research; • Summarises the pros and cons of applying CA in the field of transport research.
Empirical study	Ryan et al. (2015)	• Employs Sen's CA as a conceptual framework to explore public transport as an element of mobility among residents between 65 and 79 living in Stockholm; • Examines the relationship between mobility resources, and the perceived potential and actual use of public transport; • Examines differences in travel behaviour between non-public transport user and public transport user groups.	• Increasing residential density is more likely to have a positive influence on public transport use as mobility capability and functioning elements. • Females living alone tend to use and rely on public transport more than other socio-demographic groups; • A higher ratio of cars to household members may reduce the likelihood of using public transport as mobility capability and functioning elements.
Empirical study	Hananel and Berechman (2016)	• Provides an innovative framework based on the CA, combining justice considerations and decision-making in relation to transport services provision; • Explores the implications of the CA for the justice criteria applied in transport investment decision-making in the case of King County, in Washington State.	• CA is employed in a real-world case study, such as that of King's County. • The adoption of the CA also depends on the dominant political point of view.
Empirical study	Hickman et al. (2017)	• Uses the CA to assess the differences in transport equity across population groups and low and high income neighbourhoods in Metro Manila.	• Shows the significant differences in travel and activity participation across income, age, gender and neighbourhood in Manila.
Theoretical study	Martens (2017)	• Discusses theories about transport justice, including in relation to the CA.	• Suggests several dimensions of justice and fairness in relation to society's provision of physical accessibility; • Proposes a new framework to facilitate analysis of transport justice, using accessibility as the key analytical tool.
Empirical study	Cao and Hickman (2019)	• Uses CA as a theoretical framework to address the differences between capabilities and functionings across various socio-demographic categories in Beijing.	• Shows that functionings, capabilities, freedoms and choices differ according to an individual's socio-economic characteristics, such as gender, age, hukou, personal income and car ownership in East Beijing.

Table 2. Nussbaum's central human capabilities and application in transport planning (Developed by authors, drawing on Nussbaum, 2000, 2003, 2011).

Central Human Capability Category	Indicator	Application in Transport Planning
1. Life	Being able to survive and not to die prematurely.	• Being able to travel safely with minimal risk of accidents • Being able to access food and clothes shopping
2. Bodily Health	Being able to live with a good standard of health care, adequate food and drink, sleep, and shelter.	• Being able to access daily activities • Being able to travel actively, such as by walking, cycling and public transport • Being able to access a general practitioner (GP) or hospital
3. Bodily Integrity	Being able to access mobility and to be protected against criminal offence, injury, assault and threat.	• Being able to move from one place to another without fear of injury, assault, or threat
4. Senses, Imagination, and Thought	Being able to feel, understand, imagine, speak and think in a truly humane way, while undertaking basic daily activities (e.g. exercising freedom of choice regarding religion, literature, and music, etc.) and work and live without interruption by others; to be able to access training and education.	• Being able to access employment, education and training opportunities • Being able to access cultural and entertainment opportunities • Being able to produce good ideas, imagine and reflect on one's work and daily life, including reading, listening to music, and accessing Wi-Fi whilst travelling
5. Emotions	Being able to rely on things and other people beyond ourselves; to enjoy activities and participation; to love, grieve and care for others.	• Being able to engage in a wider range of social activities and social interaction • Being able to travel and/or meet up with family and friends • Being able to access help during the journey, if required
6. Practical Reason	Being able to exercise freedom of religious and other beliefs without punishment; to reflect and to be proud of achievements gained in life.	• Being able to use different means of transport without experiencing any discrimination • Being able to access a wide range of cultural activities
7. Affiliation	Being able to live equally and communicate with other people in a society without any discrimination or unjust judgment based upon differences in gender, race, ethnicity, national origin, sexual orientation, and religion; vulnerable groups are cared for by others.	• Being able to engage in a wider range of social activities and interaction • Being able to use different means of transport without experiencing any discrimination
8. Other Species	Being able to peacefully coexist with other species in the natural world without destroying their living environment to fulfil human demands.	• Being able to use different modes of transport without causing any adverse effects such as environmental degradation and noise pollution • Being able to use renewable and clean energy rather than fossil fuels for travel
9. Play	Being able to enjoy recreational activities, have fun, play and laugh.	• Being able to engage in a wide range of social activities and interaction
10. Control Over One's Environment	Being able to have equal opportunities to employment and work with others; efforts and achievements within the workplace are respected and recognised by others; to have access to a home; to vote and be elected and participate equally in politics and the governance of people's lives.	• Being able to access a range of employment opportunities • Being able to afford daily travel costs (i.e. only spend a low proportion of total household income on travel) • Being able to engage in political participation

3. Case study and method

3.1 Case study context

Greater London has a geographical area of 1,572 square kilometres. The total number of usual residents living in Greater London was 8.6 million in 2015. London has become an unequal city according to many metrics; for example, it contains the second highest percentage of people in the richest tenth of the population (15%), but also contains the highest percentage of people in the poorest tenth of the population nationally (15%) (Aldridge et al. 2015). In 2015, the groups in the richest tenth held £260 billion of financial wealth, whereas the poorest tenth had negative equity of −£1.3 billion (ibid.). The Mayor's Transport Strategy (2018) sets a target of improving transport and quality of life in order to ensure that London's transport system helps to shape the city and brings benefits to every Londoner (GLA 2018). Thus, transport is seen as an important means of addressing social equity and widening access to participation in activities.

The analysis in this paper concentrates on London, and particularly on neighbourhoods surrounding three Underground stations on the JLE which was opened in 1999; namely Bermondsey, Canning Town, and Canary Wharf (Figure 1). The impacts of the JLE have previously been investigated (see Jones 2015; Lane et al. 2004); however, our work complements this analysis in terms of providing a different type of analysis on social impacts. There is a mix of income groups in each neighbourhood and different average income profiles: lower income cohorts are found in Canning Town; middle income cohorts in Bermondsey; while higher income residents are found in Canary Wharf.
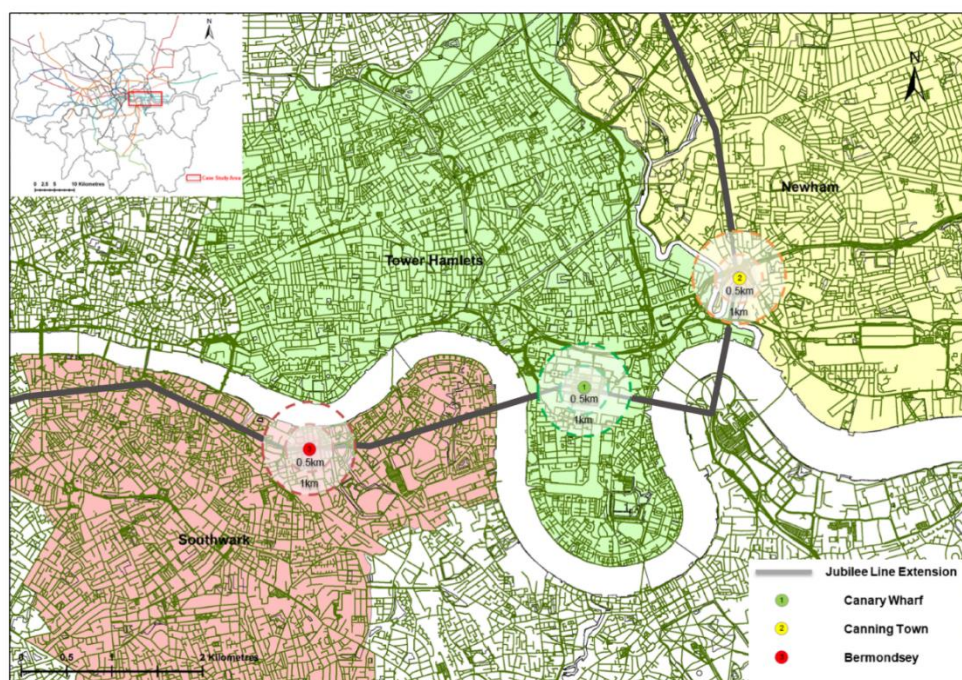

Figure 1. Case study of London (Source: authors).

3.2 Data and method

Data were collected through face-to-face surveys and a postal survey, with 602 residents responding in total in 2016 (Cao 2019). The sampling methods used in this study are similar to the previous study conducted in Beijing (see Cao and Hickman 2018, 2019). We used a random sampling approach (Fink 2003; Valliant et al. 2013) to select and carry out the interviews with people who were walking either near their local communities within the station catchment area or at the underground station[3]. In addition, we also applied a systematic sampling approach to select households (Fink 2003; Pfeffermann and Rao 2009) in the local neighbourhood, whom we then posted surveys to. Descriptions of the variables are provided in Table 3, with survey questions covering all of the capability and functioning topics described earlier in Table 2. Brief descriptive statistics are shown in Table 4.

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[3] We asked the interviewees whether or not they lived in the local station catchment area. If we found respondents who did not fulfil our sample requirements, the interview would then be stopped. We also checked their residence afterwards, based on one of the survey questions asking for their home addresses and postcodes.

Table 3. Descriptions of variables.

Categories	Variable Names	Description (Measure and Value)
Socio-demographics		
Gen	Gender	1(female); 0(male)
Age	Age	1(18-24); 2(25-34); 3(35-44); 4(45-54); 5(55-64); 6(65 or over)
Eth	Ethic origin	1(white); 0(otherwise)
Mas	Marital status	1(yes); 0(otherwise)
Inp	Incumbent population	1(moved to the area before the corresponding underground stations were opened); 0(otherwise)
Emp	Employment	1(if employed/self-employed); 0(otherwise)
Pmi	Personal annual income	Personal annual income in GBP: 1(<6,000); 2(6,001-14,000); 3(14,001-20,000); 4(20,001-32,000); 5(32,001-43,000); 6(43,001-64,000); 7(64,001-100,000); 8(>100,001)
Hst	Housing tenure	1(owned); 0(otherwise)
Cao	Car Ownership	1(yes); 0(otherwise)
Capabilities and Functionings	***(C&F)***	
Life		
LItrs	C&F_travel safety (accidents)	Index of functionings/capabilities
LIshp	C&F_access grocery/clothes shopping	Index of functionings/capabilities
Bodily Health		
BHhos	C&F_access hospitals	Index of functionings/capabilities
BHact	C&F_active travel	Index of functionings/capabilities
Bodily Integrity		
BItrs	C&F_travel safety (violent assault)	Index of functionings/capabilities
Senses, Imagination, and Thought		
SItre	C&F_access training and education	Index of functionings/capabilities
SIcri	C&F_creativity and imagination	Index of functionings/capabilities
SIree	C&F_ exercise freedom of religious/worship/practise	Index of functionings/capabilities
Emotions		
EMtrv	C&F_travel and visit family/friends	Index of functionings/capabilities
Practical Reason		

	PRcua	C&F_access cultural activities	Index of functionings/capabilities
Affiliation			
	AFreh	C&F_get help	Index of functionings/capabilities
Other Species			
	OSend	C&F_against environmental degradation	Index of functionings/capabilities
Play			
	PLler	C&F_leisure and recreation	Index of functionings/capabilities
Control Over One's Environment			
	COwoo	C&F_seek work opportunities	Index of functionings/capabilities
	COtra	C&F_travel affordability	Index of functionings/capabilities
	COpop	C&F_political participation	Index of functionings/capabilities
Note:		C&F = Capabilities and Functionings.	
		'Not applicable' responses in the survey research are treated as missing values in statistical terms. Therefore, the sample sizes used in the analysis are 527.	

Table 4. Descriptive statistics.

Individual Characteristics		Bermondsey (n=125)		Canning Town (n=118)		Canary Wharf (n=284)		London (n=527)		Londoners - Census (2011) (n=3,734,844)[4]		Commuters - Census (2011) (n=793,455)[5]	
		Frequency	Percentage	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
Gender	Male	66	52.8%	54	45.8%	152	53.5%	272	51.6%	1,974,171	52.9%	494,129	62.3%
	Female	59	47.2%	64	54.2%	132	46.5%	255	48.4%	1,760,673	47.1%	299,326	37.7%
Age[6]	18-24	6	4.8%	24	20.3%	33	11.6%	63	12.0%	469,815	10.4%	384,579	10.8%
	25-34	64	51.2%	58	49.2%	167	58.8%	289	54.8%	1,383,723	30.7%	1,113,476	31.3%
	35-44	29	23.2%	13	11.0%	49	17.3%	91	17.3%				
	45-54	12	9.6%	15	12.7%	19	6.7%	46	8.7%	2,547,910	56.6%	1,979,786	55.6%
	55-64	8	6.4%	2	1.7%	10	3.5%	20	3.8%				

[4] Reference: gender only. It should be noted that the total frequency for each of the corresponding individual characteristics drawn from Census (2011) may vary, as some figures have been obscured in order for data to be made publicly available (GLA 2012-2017).

[5] Same as above - footnote 4.

[6] Age: all data from Census (2011) are counted as aged 16+. Data in our survey are counted as aged 18+.

	>65	6	4.8%	6	5.1%	6	2.1%	18	3.4%	102,647	2.3%	81,964	2.3%
Marital status	Yes	37	29.6%	22	18.6%	116	40.8%	175	33.2%	N/A		N/A	
	No	88	70.4%	96	81.4%	168	59.2%	352	66.8%				
Ethnicity	White UK	47	37.6%	24	20.3%	44	15.5%	115	21.8%	1,761,270	47.2%	642,402	81.3%
	White other	34	27.2%	35	29.7%	79	27.8%	148	28.0%	698,320	18.7%	53,341	6.8%
	Asian	4	3.2%	23	19.5%	109	38.4%	136	25.8%	635,461	17.0%	52,122	6.6%
	Black	25	20.0%	20	17.0%	6	2.1%	51	9.7%	408,760	10.9%	23,590	3.0%
	Others	15	12.0%	18	13.5%	46	16.2%	77	14.7%	231,033	6.2%	18,378	2.3%
Highest educational attainment	Secondary school or lower	6	4.8%	8	6.8%	6	2.1%	20	3.8%	1,586,374	28.8%		
	College or equivalent	12	9.6%	12	10.2%	14	4.9%	38	7.0%				
	Bachelor's degree or equivalent	47	37.6%	46	39.0%	73	25.7%	166	31.5%	3,916,512	71.2%		
	Master's degree or higher	60	48.0%	52	44.1%	191	67.3%	303	57.5%				
Employment	Full-time	88	70.4%	62	52.5%	199	70.1%	349	66.2%				
	Part-time	6	4.8%	10	8.5%	19	6.7%	35	6.7%	N/A			
	Self-employed	16	12.8%	12	10.2%	16	5.6%	44	8.4%				
	Student	5	4.0%	23	19.5%	46	16.2%	74	14.0%				
	Unemployed and others	10	8.0%	11	9.3%	4	1.4%	25	4.7%			N/A	
Housing tenure	Own	35	28.0%	40	33.9%	103	36.3%	178	33.8%	1,618,315	49.5%		
	Rent	90	72.0%	78	66.1%	181	63.7%	349	66.2%	1,647,858	50.5%		
Personal income (GBP)	<6,000	5	4.0%	26	22.0%	36	12.7%	67	12.7%				
	6,000-14,000	10	8.0%	16	13.6%	31	10.9%	57	10.8%				
	14,001-20,000	12	9.6%	10	8.5%	11	3.9%	33	6.3%				
	20,001-32,000	47	37.6%	35	29.7%	41	14.4%	123	23.3%	N/A			
	32,001-43,000	12	9.6%	12	10.2%	41	14.4%	65	12.3%				
	43,001-64,000	16	12.8%	12	10.2%	38	13.4%	66	12.5%				
	>64,000	23	18.4%	7	5.9%	86	30.3%	116	22.0%				
	Yes	101	80.8%	80	67.8%	201	70.8%	382	72.5%				

Driving licence	No	24	19.2%	38	32.2%	83	29.2%	145	27.5%
Others									
When moved into the area	1999 or before	21	16.8%	22	18.6%	26	9.2%	69	13.1%
	between 2000-2010	29	23.2%	26	22.2%	55	19.4%	110	20.9%
	2011 or later	75	60.0%	70	59.3%	203	71.5%	348	66.0%
Work in the same area	Yes	20	16.0%	25	21.2%	58	20.4%	103	19.5%
	No	105	84.0%	93	78.8%	226	79.6%	424	80.5%

There are clear differences in individual characteristics between the three types of neighbourhood (Table 4). In a relatively lower-income area, Canning Town, there are more females (54.2%, compared to 47.2% and 46.5% in the middle- and higher-income neighbourhoods of Bermondsey and Canary Wharf, respectively); a difference in the age profile, with fewer people in the 25-34 group (49.2% compared to 51.2% and 58.8% in Bermondsey and Canary Wharf, respectively) but more aged over 65 (5.1% compared to 4.8% and 2.1%); lower levels of educational attainment, with more people having less than a college degree or equivalent (6.8% compared to 4.8% and 2.1%); more single residents (81.4% compared to 70.4% and 59.2%); lower annual personal income, particularly in the over £64,000 bracket (5.9% compared to 18.4% and 30.3%); and a larger incumbent population before the JLE opened (18.6% compared to 16.8% and 9.2%). In addition, to some extent, our samples are most likely to represent residents living in the station catchment areas across London rather than strictly scaling up to represent all of Greater London. However, we have still used London Census (2011) data representing all Londoners and commuters, respectively, as a reference, (GLA 2012-2017).

The capabilities and realised functionings questions follow the format given below in Example 1 (Cao and Hickman 2018, 2019). Capabilities are the most difficult to apply, representing the 'real opportunities' that individuals may have. We interpret capabilities, in this paper, as the opportunities that individuals expect to have in terms of travel or access to activities. In other words, capabilities are measured subjectively, by questioning respondents based on their perceptions of travel and activity, while functionings relate to realised travel and activity. For example, in the survey, respondents are asked whether they are able to visit friends and family if: (1) ideally they could use whatever form of transport they needed (capability), relative to (2) the available transport modes (functioning). This makes the question easier for respondents to understand based on perceptions of ideal opportunity. The questions differ by each indicator and the survey is available in Cao (2019). The measurement of capabilities is difficult and it would be useful to test different approaches in future research. Functionings are easier to understand, representing actual travel and activities.

In addition, in order to ensure the respondents could understand our questions clearly, especially those relating to their capabilities, we tested seven different ways of measuring people's expected travel opportunities/perceived accessibility over several rounds via pilot studies. The method shown in Example 1, below, was found to be the most effective. Therefore, a final pilot study was carried out using Example 1. We tested the survey with 38 people, and this was followed by a short interview with each of the respondents. 35 out of the 38 respondents were found to have accurately understood the general meaning in relation to measuring their capabilities and functionings in our survey. Therefore, we ultimately decided to use Example 1 as our final version of the sample survey.
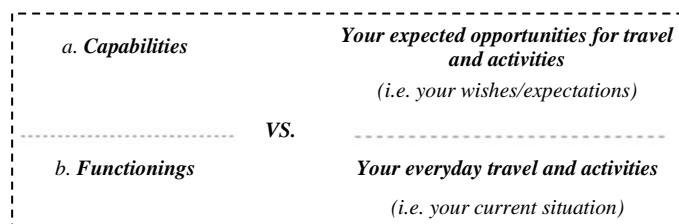
Example 1:[7]

*Example (EMtry): Within London, I would be able to **visit my family or meet up with friends:***
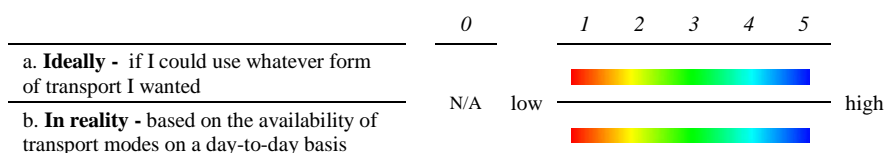
In order to measure the differences across population groups, the basic test statistic employed was an F-test (see Blackorby et al. 1981; Foster and Shneyerov 2000). This method is also used in Lorgelly et al.'s (2008) work and a similar approach is used to test transport-related social inequities in Cao and Hickman's (2018, 2019) and Hickman et al.'s (2017) studies. The F-statistic was employed to examine any statistically significant differences in terms of the capabilities and functionings across the socio-demographic characteristics of individuals and different neighbourhoods in London. Then, we calculated the means for the corresponding indices and compared the figures across different social groups and neighbourhoods (e.g. see Section 4.2). In the analysis, it is assumed that the further the capabilities, and/or functionings, and/or the gap between them (which could be viewed as a form of travel inequity) are spread out, the higher the value of the variability in the numerator of the F-statistic.[8]

4. Transport-related social equity

4.1. Differences by population group

Nine socio-demographic variables were used to examine transport-related social equity issues, namely: gender, age, ethnic origin, marital status, incumbent or incoming population, employment, personal income, housing tenure and car ownership. 16 indicators were identified to represent the social impacts, reflecting the capabilities and functionings concepts. Statistically significant findings are indicated with an asterisk (*). Table 5 gives a summary of the F-test statistics.

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[7] Example 1 consists of LIshp, BHhos, SItre, SIree, EMtry, PRcua, PLler, COwoo, and COpop (see Table 3)
[8] The equation and more detailed explanation of the F-statistic are given in Cao (2019) and Cao and Hickman (2018, 2019).

Table 5. Summary test statistics (F tests) for differences in individual social equity by population group.

Capabilities and Functionings	Gender	Age	Ethic Origin	Marital Status	Incumbent Population	Employment	Personal Income	Housing Tenure	Car Ownership
	A	B	C	D	E	F	G	H	I
Life									
C_travel safety (accidents)	22.948***	18.073***	0.366	1.610	6.690**	0.002	4.236*	2.561	2.853
F_travel safety (accidents)	3.920*	2.976	2.262	0.915	1.880	1.248	7.754**	3.208	6.880**
C_access grocery/clothes shopping	8.355**	4.550*	4.503*	0.000	2.163	0.259	3.157	0.784	5.360*
F_access grocery/clothes shopping	8.426**	9.935**	35.643***	2.322	37.426***	0.472	0.579	1.392	0.013
Bodily Health									
C_access hospitals	2.941	0.016	0.005	7.203**	1.573	0.680	0.425	0.009	2.777
F_access hospitals	2.033	10.173***	9.223**	1.187	0.743	3.209	1.200	2.290	20.919***
C_active travel	36.196***	23.930***	49.300***	0.997	1.900	3.537	31.847***	24.733***	3.650
F_active travel	0.002	5.089*	25.624***	2.711	0.713	0.352	25.818***	19.068***	2.009
Bodily Integrity									
C_travel safety (violent assault)	64.648***	25.063***	22.095***	2.066	0.094	10.271***	33.130***	10.627***	0.001
F_travel safety (violent assault)	40.618***	18.639***	5.021*	1.552	0.301	9.795*	24.050***	4.799*	0.014
Senses, Imagination, and Thought									
C_access training and education	15.128***	3.410	9.375**	0.253	10.783***	9.655**	2.471	0.283	0.397
F_access training and education	0.493	20.184***	2.053	0.042	11.025***	3.918*	0.033	1.598	0.024
C_creativity and imagination	18.540***	1.144	24.386***	4.113*	20.106***	0.249	6.434*	15.153***	0.260
F_creativity and imagination	0.197	0.135	6.484*	4.779*	11.806***	2.152	1.360	7.644**	1.781
C_religious exercise	10.547***	2.025	0.067	4.685*	11.984***	6.427*	1.227	1.527	2.100
F_religious exercise	6.966**	14.950***	0.726	4.446*	25.312***	0.522	2.846	0.122	0.858
Emotions									
C_travel and visit family/friends	3.924*	9.563**	0.081	2.240	0.727	0.018	0.579	4.922	0.354
F_travel and visit family/friends	4.058*	12.519***	30.862***	2.969	19.788***	0.975	3.923*	5.498	2.834
Practical Reason									
C_access cultural activities	17.892***	5.073*	2.183	3.129	0.327	11.945***	0.173	0.003	0.001
F_access cultural activities	15.316***	3.934*	27.128***	2.451	8.216**	0.001	6.584**	4.534*	5.743*
Affiliation									
C_respect and get help	0.005	22.414***	33.822***	25.829***	10.772***	0.670	0.031	23.374***	15.263***
F_respect and get help	0.052	9.082**	13.501***	0.067	16.039***	1.364	0.024	27.678***	14.513***
Other Species									
C_against environmental degradation	38.625***	9.983**	23.139***	20.706***	4.963*	4.706*	6.445*	9.030**	7.345**
F_against environmental degradation	0.221	0.450	1.605	18.811***	7.956**	0.086	0.028	8.018**	1.032
Play									
C_leisure and recreation	3.057	11.614***	9.291**	3.093	8.186**	5.120*	0.252	0.013	0.272
F_leisure and recreation	3.950*	19.714***	37.842***	0.187	32.055***	0.153	6.528*	0.672	0.164
Control Over One's Environment									
C_seek work opportunities	13.977***	0.529	0.856	2.943	3.215	8.824**	4.962*	1.286	0.399
F_seek work opportunities	1.408	13.668***	8.142**	0.530	17.201***	1.140	0.756	13.321***	5.302*

C_travel affordability	71.167***	10.851***	24.196***	13.671***	5.965*	2.690	65.018***	49.878***	0.787
F_travel affordability	7.218**	1.132	6.215*	2.594	5.509*	0.289	17.454***	14.346***	19.110***
C_political participation	10.325***	10.690***	1.082	2.486	11.178***	2.968	0.065	0.305	0.282
F_political participation	0.031	32.099***	15.923***	3.821	25.343***	3.560	1.427	0.265	5.172*

(n=527)

Note: 1. *p<0.05, **p<0.01, ***p<0.001.

2. Key results are highlighted with a dotted outline box and discussed in the text.

3. More detailed statistical analysis relating to Table 5 and further interpretation of the findings can be found in Cao (2019).

In terms of gender (Column A), females are more likely to be concerned about their individual travel safety than males, both in terms of traffic accidents and potential violent assault, and for the capability and functioning categories. Females generally appear to have higher scores for those activities which tend to be traditionally associated with women, such as 'accessing grocery'; 'accessing cultural activities'; and 'visiting family and friends'. These results are consistent with the empirical study conducted in Beijing (Cao and Hickman 2019).

Most members of the younger generation (Column B), particularly those aged between 18 and 34, have lower levels of both capabilities and functionings compared with older age groups in relation to most activities, including: 'accessing grocery', 'accessing cultural activities', 'accessing leisure and recreation', and 'political participation'. The older generation are more likely than their younger counterparts to be able to engage in active travel, such as walking and cycling, both in their local area and across London. Younger adults appear to rely more on public transport (e.g. Underground) than older age groups, at least in our sample.

In relation to ethnic origin (Column C), white respondents have much higher scores than Black, Asian and Minority Ethnic people (BAME) for most activities, particularly in terms of functionings, such as 'accessing grocery'; 'accessing hospitals'; 'performing active travel'; 'travelling around safely (violent assault)'; 'travelling and visiting family/friends'; 'accessing cultural activities and recreation'; 'seeking job opportunities'; 'being able to afford daily travel costs'; and 'participating in political activities'. This is consistent with other researchers who have stated that social inequity and poverty issues are more severe for BAME groups than the white population (Barnard and Turner 2011; Bullard et al. 2004; Lucas et al. 2001; Lucas 2004; Sanchez et al. 2007; Titheridge et al. 2014). As well as inequality in incomes, this could also be due to other cultural and language barriers (DfT 2003; Lucas et al. 2001). For example, some BAME groups may prefer to stay at home with their families rather than going out and socialising with other groups. Some may be lacking in oral and written English skills, making it difficult for them to be able to communicate with the majority population and engage more widely in social activities (NCPC 2006; Payne et al. 2005). Personal safety issues should also be taken into consideration, as emphasised by Lucas et al. (2001), in that they may be fearful of threat, robbery, theft, sexual harassment, local gangs or racial abuse.

Married people (Column D) appeared to have higher levels of both capabilities and functionings compared with single people in terms of participating in activities, being able to use different modes of travel that do not cause adverse effects (e.g.

environmental degradation or noise pollution), and being able to enjoy reading, listening to music or using Wi-Fi during the journey.

The incumbent population (those who lived in the Underground station catchment areas before the JLE was built) (Column E) were more likely to score higher, for capabilities and functionings, relative to incomers. This finding is contrary to those of previous studies (e.g. Jones 2015; Lane et al. 2004), in which it was found that incomers gained most benefit from the JLE, certainly in terms of access to employment. There may be a number of reasons for this; perhaps the most recent incomers have to spend a large proportion of their household budget on rent, hence there may be a generational issue in participating in activities. Another possible explanation could be that some members of the incumbent population are people who chose to re-locate to the station catchment areas because they were aware that the metro would be opening soon (i.e. they were really in-movers but were still categorised as belonging to one of the types of incumbent residents due to the fact that they moved in before the metro opened). This is an issue that requires further exploration.

People in employment (Column F) were usually able to travel around safely both in their local area and across London without fear of injury, threat or violent assault. Although the average mean scores and deviations across the 'accessing training and education' indicator show that employed groups generally had lower scores for capabilities and functionings compared to unemployed people. The gap between capabilities and functionings was found to be highest for unemployed people, at 0.67 compared to 0.54 for those in employment. Student respondents were also classified as unemployed, which may contribute to this finding.

Income (Column G), has conventionally been found to be a significant factor influencing travel behaviour, with lower income groups more likely to experience social exclusion and have lower rates for participating in activities relative to higher income cohorts. This is corroborated in this research. People with higher incomes generally also had higher levels of capabilities and functionings than lower income groups, particularly with regard to 'travel safety (accidents and violent assault)'; 'travel affordability'; and 'active travel'.

In terms of housing (Column H), people who owned their own houses were more likely to have higher average scores for capabilities and functionings relative to people who rented properties, particularly in relation to activities such as 'active travel', 'travel safety (violent assault)', 'creativity and imagination', 'against environmental degradation'; and 'travel affordability'. These significant indicators may partly reflect the persistence of income-related social inequity.

Finally, looking at the differences relating to car ownership (Column I), first, it was found that people who owned cars tended to have higher capabilities in terms of 'accessing grocery and clothes shopping' compared to non-car owners. The results imply that having a car may facilitate and enhance people's expected opportunities, such as going shopping, because car owners tend to have greater mobility and opportunities than those without cars (Foley 1999). There was no significant difference in terms of functionings between car owners and non-car owners. However, this can be partly explained by respondents living in the station catchment areas; thus, they could

easily go shopping by public transport or on foot.

4.2. Differences by station catchment area
Similarly there are interesting differences across station areas (Table 6).

Table 6. Summary test statistics (F tests) for differences in individual social equity by neighbourhood and statistically significant values for each of the corresponding neighbourhoods.

Capabilities and Functionings	Neighbourhood	Bermondsey	Canning Town	Canary Wharf
	F Values	Capabilities and Functionings Scores (SE)		
Life				
C_travel safety (accidents)	0.120	-	-	-
F_travel safety (accidents)	5.992**	4.09 (0.064)	3.81 (0.066)	4.04 (0.042)
C_access grocery/clothes shopping	0.065	-	-	-
F_access grocery/clothes shopping	2.528	-	-	-
Bodily Health				
C_access hospitals	0.294	-	-	-
F_access hospitals	0.249	-	-	-
C_active travel	10.768***	3.67 (0.077)	3.14 (0.085)	3.33 (0.055)
F_active travel	27.892***	4.31 (0.057)	3.54 (0.084)	3.92 (0.050)
Bodily Integrity				
C_travel safety (violent assault)	2.097	-	-	-
F_travel safety (violent assault)	9.986***	4.00 (0.065)	3.59 (0.075)	3.67 (0.047)
Senses, Imagination, and Thought		-	-	-
C_access training and education	2.767	-	-	-
F_access training and education	3.997*	3.89 (0.077)	3.59 (0.087)	3.82 (0.052)
C_creativity and imagination	4.999**	3.26 (0.088)	3.46 (0.096)	3.12 (0.058)
F_creativity and imagination	3.464*	3.25 (0.088)	3.51 (0.092)	3.24 (0.056)
C_religious exercise	3.394*	4.27 (0.091)	3.99 (0.096)	3.97 (0.068)
F_religious exercise	1.295	-	-	-
Emotions				
C_travel and visit family/friends	3.236*	4.63 (0.058)	4.43 (0.062)	4.54 (0.036)
F_travel and visit family/friends	1.853	-	-	-
Practical Reason				
C_access cultural activities	8.058***	4.63 (0.046)	4.29 (0.066)	4.43 (0.042)
F_access cultural activities	7.018***	4.00 (0.066)	3.60 (0.083)	3.79 (0.050)
Affiliation				
C_respect and get help	4.898**	3.98 (0.078)	3.73 (0.083)	3.69 (0.048)
F_respect and get help	6.716***	3.81 (0.079)	3.56 (0.081)	3.46 (0.054)
Other Species				
C_against environmental degradation	8.607***	3.45 (0.080)	3.01 (0.089)	3.36 (0.053)
F_against environmental degradation	4.533*	3.55 (0.082)	3.26 (0.082)	3.51 (0.048)
Play				
C_leisure and recreation	1.715	-	-	-

F_leisure and recreation	1.356	-	-	-
Control Over One's Environment				
C_seek work opportunities	3.250*	3.98 (0.093)	4.27 (0.074)	4.16 (0.055)
F_seek work opportunities	5.425**	3.33 (0.086)	3.68 (0.082)	3.65 (0.059)
C_travel affordability	5.196**	3.32 (0.091)	3.27 (0.090)	3.55 (0.050)
F_travel affordability	6.795***	3.58 (0.088)	3.69 (0.073)	3.90 (0.047)
C_political participation	4.417*	4.08 (0.083)	3.77 (0.101)	3.74 (0.070)
F_political participation	1.073	-	-	-
(n=527)		(n=125)	(n=118)	(n=284)

Note: *p<0.05, **p<0.01, ***p<0.001.

Table 6 shows a summary of the F-test statistics reflecting the concepts of capabilities, functionings spatially across the three mixed-income neighbourhoods located in each of the station catchment areas, as well as giving the specific statistically significant capabilities and functionings scores for each of the neighbourhoods. The results show that residents living in the relatively lower-income area of Canning Town reported experiencing travel safety issues (accidents and violent assault) in the local area, with lower functionings scores of 7.40, compared to the other two neighbourhoods of Bermondsey and Canary Wharf, which were valued at 8.09 and 7.71, respectively. In terms of active travel, again, people living in Canning Town were less likely to be able to walk or cycle both in the local area and across London compared to their other counterparts in the other two neighbourhoods. Furthermore, we found that people living in Canning Town not only had the lowest capabilities and functionings scores, valued at 4.29 and 3.60, respectively, but they also had a gap between these scores compared to their counterparts in Bermondsey and Canary Wharf (0.69 compared to 0.63 and 0.64), particularly with regards to accessing cultural activities. This implies that people living in a relatively lower-income area may have high travel expectations, but they are faced with more accessibility barriers based on the availability of their chosen transport modes on a daily basis, especially compared to people living in middle- or higher-income neighbourhoods. Furthermore, in terms of seeking work opportunities, the results show that residents living in Canary Wharf had relatively lower scores for both capabilities and functionings, valued at 4.16 and 3.65, respectively, compared to people living in Canning Town with scores of 4.27 and 3.68. There was also a lower gap between scores found for respondents living in a higher-income neighbourhood compared to people living in a lower-income area (0.51 relative to 0.59). This can be explained by the fact that residents living in Canary Wharf had the third lowest unemployment rate recorded in Tower Hamlets at 8.2%, which was significantly below the local borough rate for the economically active population, while the majority of people living in Canary Wharf were working in much higher professional and managerial occupations, with a score of 54.6%, compared to the local borough average of 36.1% (Tower Hamlets Council 2014).

5. Discussion and conclusions

This paper is innovative in applying the CA framework in the transport context and in

relation to people's experience of their journeys. It is important to understand why physical accessibility may not be an effective measure, by itself, to understand how travel and activity participation differs across population groups. This paper has evaluated individual social equity impacts in relation to transport, focusing on people living in the catchment areas of the JLE, and socio-demographic characteristics of people living in the catchment areas of three London Underground stations: Bermondsey, Canning Town, and Canary Wharf. This allows the differences between capabilities, functionings, and the gap between these to be analysed. Differences between opportunities and travel experience or activities can be seen both across population groups and spatially.

There are statistically significant differences for capabilities and functionings across individuals' socio-demographic characteristics, including by gender, age, ethnicity, marriage, incumbent residents, employment, income, house tenure and car ownership. This corroborates previous findings on transport and social equity (such as Bocarejo and Oviedo 2012; Jones 2015; Lucas 2004; Lucas, 2012; Lucas et al. 2001; Martens and Di Ciommo 2017; Preston and Rajé 2007; Titheridge et al. 2014), but adds the additional dimension of comparing perceived opportunities and actual experience and activity by using the CA. We argue that there can be important differences between an individual's capabilities and their functionings in terms of travel. Physical accessibility is often not taken up by different groups to different degrees, according to various barriers to access. Hence it is only by considering capabilities and functionings that these barriers can be understood, and, eventually, removed. Travel equity has always been difficult to define and perhaps both capabilities and functioning can be used as useful indicators.

With regards to the differences by station catchment area, this analysis shows socio-spatial differences across neighbourhoods in London, although the residents have similar levels of physical accessibility to the local Underground stations. In general, most residents living in a relatively low income neighbourhood are more likely to have lower capabilities and functionings scores for certain multidimensional social indicators (such as life, bodily health, emotions, etc.) compared to their counterparts who live in middle- and higher-income areas. Understanding capabilities and functionings can help to identify the actual gap that exists between the real opportunities available to people in a particular context and how this may differ from their actual participation in activities. The barriers to using accessibility may be higher for residents living in lower-income areas compared to their counterparts in middle- and higher-income neighbourhoods (e.g. for 'accessing cultural activities' and 'seeking work opportunities').

The method adapted from Nussbaum's (2003) 10 central human capabilities, and applied in the transport domain, enables the subjectivities associated with the abstract concept of CA to be quantified to some extent. This takes forward previous work on CA in relation to transport (e.g. Beyazit 2011; Cao and Hickman 2018, 2019; Hananel and Berechman 2016; Hickman et al. 2017; Martens 2017; Pereira et al. 2017; Ryan et al. 2015; Tyler 2006). It is also suggested that the CA can be further applied as a conceptual framework for understanding social equity in the transport field and that

this paper contributes to doing so.

Some reflections are offered on further research and policy implications. In research terms, we can examine the capabilities concept further and use different ways to assess this. The capabilities concept not only shows the opportunities available to each person, but also reflects individuals' choices or freedoms, and the freedoms or opportunities created by a combination of personal abilities and the political, social, and economic environment (Nussbaum 2011). Therefore, we suggest that further research into people's capabilities can also help us to gain more insight into different individuals' attitudes towards their choice of travel mode. Encouraging more people to use a sustainable transport system is something that can only be achieved over time. Thus, the capabilities concept can be used as one of the key indicators to determine individuals' attitudes, and be integrated with other socio-economic characteristics to measure people's travel behaviour, in order to gain a better understanding of what key factors affect their choice of transport modes.

There are some limitations to this study. The concept of capabilities could be difficult to understand and may not lend itself to being measured by surveys. We therefore suggest that qualitative research, such as in-depth interviews, could also be used to supplement the survey results and help to understand the real opportunities available to people in terms of transport-related social equity, which is the most difficult aspect of applying the CA. In addition, the stark contrast between the richest 10% and poorest 10% of the population is not reflected across the three station areas. Therefore, it would be useful to conduct further research using other neighbourhoods which are more representative of these large differences.

General policy implications can be derived from this research in several ways. First, in London, mitigating social inequity in transport is predominantly a top-down project involving policy-makers from DfT, TfL, boroughs, and wider organisations. Without a more in-depth understanding of local residents' real travel needs, the issues associated with transport-related social inequity may be difficult to resolve. Second, there is no 'one-size-fits-all' blueprint to enable policy-makers to fully understand social inequity in relation to transport in terms of people's real mobility needs and levels of travel inequity. It is suggested that the adapted multi-dimensional social indicators (Table 2) could be used alongside existing policy approaches to assist in assessing transport-related social inequity. Policy-oriented studies on transport and social equity require both qualitative and data-based analysis to help understand the issues at hand. Travel experiences and participation in activities and life should be much more equitable than at present, where we can clearly see significant differences by population group and by location. Plato's aspirations for the Just Polis require transport infrastructure and cities to be designed so that they facilitate social equity – at the moment, the reverse appears to be more evident.

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