15. Using different approaches to evaluate individual social equity in transport

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ABSTRACT

Inequalities not only exist in the field of economics in relation to income and wealth, but also in other areas, such as the transport sector, where access to and use of different transport modes varies markedly across population groups, and which provides the means to access everyday living activities. A key concern within the transport sector is that inequality has extended beyond the traditional measures of travel, and now covers a wide range of effects relating to social exclusion, freedom, well-being and being able to access reasonable opportunities and resources. In order to address the aforementioned issues, an important question to resolve is what type of methods can be used to measure inequalities in transport most effectively. Therefore, this study aims to apply different approaches, including the Capabilities Approach (CA) and a further six inequality indices, namely the Gini coefficient, the Atkinson index, the Palma ratio, the Pietra ratio, the Schutz coefficient and the Theil index, to the case study using the relatively migrant-rich lower-income neighbourhood of Tuqiao, in Beijing, in order to assess individual transport-related social inequity issues. The findings suggest that the CA is useful in assessing transport-related inequalities where there are significant barriers to the take up of accessibility, for example where there are high levels of disadvantaged groups and disaggregated analysis can be undertaken. The Palma ratio appears to have a larger effect than the Gini coefficient and the other inequality indices when measuring transport-related social inequity. In addition, we also found that most income inequality methods adapted from econometrics may be better suited to measuring transport-related social inequity between different regions, cities or countries, or within the same area, but at different points in time, rather than to measuring a single neighbourhood as a whole. Finally, we argue that to what extent politicians or transport planners can use appropriate management tools to measure transport-related social inequalities may be significant in terms of the progress that can be made in the fight against social inequity in the transport field.

KEYWORDS

Transport; travel behaviour; social equity; inequality methods; the Capabilities Approach; Beijing.

1. INTRODUCTION

There is growing inequality in the distribution of opportunities and activities, particularly with regard to income and wealth[1], not only in the so-called developing countries (Ravallion, 2014), but throughout the world (Alvaredo et al., 2018). The World Inequality Report shows that the richest 10 per cent of people received approximately 61 per cent, 55 per cent, 55 per cent, 47 per cent, 46 per cent, 41 per cent and 37 per cent of national income in the Middle East, India, Brazil, USA, Russia, China and Europe, respectively, in 2016 (ibid.). These are fairly damning statistics globally from the perspective of social equity. In addition, Dorling (2015) argues that the top one per cent of people generally exacerbate this inequality, because they have an excessive amount of money and benefit disproportionately from this extreme wealth, whereas there is less potential for the remaining 99 per cent of people to enhance their financial status. Hence, the rich become richer, and the poor become poorer (OECD, 2015). Inequalities not only exist in the field of economics in relation to income and wealth, but also in other areas, such as the transport sector, where access to and use of different transport modes varies markedly across population groups, and provides the means to access activities necessary in life (Martens, 2017; Banister, 2018; Litman, 2018).

In the transport context, it has been found that the rich tend to make longer distance journeys, often by rail and air, and travel more frequently. This means that wealthier cohorts generally have higher levels of mobility than their less well-off counterparts, which may in turn contribute to rising transport inequality (Banister, 2018). In addition, it has also been argued that inequality in transport has extended beyond the traditional measures of travel undertaken by different people, such as travel time, travel distance, travel mode and travel cost. Instead, it now covers a wide range of effects relating to social exclusion, freedom, well-being and the ability to access opportunities and resources (Lucas, 2004, 2012; Delbosc and Currie, 2011a, 2011b; Hickman et al., 2017; Banister, 2018; Cao and Hickman, 2019a, 2019b). In order to address the aforementioned issues, an important question to resolve is what type of methods can be used to measure inequalities in transport most effectively. Some econometric measures of income inequality have already been adapted and used to a limited extent in the transport sector, such as the Gini coefficient (Delbosc and Currie, 2011c; Lucas et al., 2016; Guzman et al., 2017), which is more widely used in development studies. However, it can be argued that if people have very similar levels of accessibility to local transport services (e.g. using the Underground), the Gini coefficient may not be the most suitable method to use, and perhaps alternative approaches could prove useful. The Capabilities Approach (CA) (Sen, 1985, 1999, 2009) has attracted increasing interest in transport, but with some difficulties noted in application (Hickman et al., 2017, Cao and Hickman, 2019a, 2019b). Beyond these approaches, it is useful to consider whether other methods can also be used to measure social equity in the transport context. To our knowledge, there are very few empirical studies[2] that have attempted to examine different inequality measures and their use in assessing individual social inequity in transport (Banister, 2018). Furthermore, only a few empirical studies have applied the CA in the transport context to examine the differences between real opportunities and actual travel and participation in activities (Hickman et al., 2017). Finally, existing literature has not

[1] The difference between income and wealth is explained by Banister (2018, p. 19).

[2] E.g. see Banister (2018, Chapter 4 Travel Patterns in Great Britain, pp. 103-110).

provided sufficient empirical studies on immigrants' travel behaviour (Blumenberg and Smart, 2010; Lovejoy and Handy, 2011), especially in developing countries (Li and Zhao, 2018). Thus, this chapter aims to fill the aforementioned research gaps using the relatively migrant-rich lower-income neighbourhood of Tuqiao, in Beijing, as a case study. As well as the CA, the following six inequality indices, namely the Gini coefficient, the Atkinson index, the Palma ratio, the Pietra ratio, the Schutz coefficient and the Theil index, are also applied and compared, in order to identify the differences between them with respect to measuring transport-related social inequity in the case of Tuqiao.

The chapter is organised as follows: section 2 introduces the case study, research framework and data; section 3 discusses the different methods used to measure social inequity; and section 4 reveals the modelling results and provides a commentary. Finally, section 5 summarises the findings, highlights the key contributions and discusses the policy implications.

2. CASE STUDY, RESEARCH FRAMEWORK AND DATA

East Beijing, and the Tongzhou District in particular (formerly located in a peripheral or suburban area covering 906 km^2, with approximately 747,000 permanent residents), was promoted to the deputy administrative centre of Beijing in July 2015, according to the "Outline of Coordinated Development for the Beijing-Tianjin-Hebei Region" (MLR, 2015). The aim was to relocate non-essential functions within Beijing while exploring a new model of optimised integrated development in a region with a dense population, as well as maintaining a good balance between jobs and housing. In Beijing, most jobs and public facilities are concentrated within the Fourth Ring Road, rather than in suburban areas like Tongzhou, which was formerly referred to as a 'dormitory satellite town'. This changed focus has led to social inequalities, including in terms of the commuting burden, due to a mismatch between jobs and housing (Zhang et al., 2018), as well as causing smog-related air pollutants and carbon dioxide emissions generated by on-road vehicles (Cao et al., 2017). Tuqiao, located within the Tongzhou District, adjacent to the East Sixth Ring Road, was selected as the case study in order to illustrate features of a mixed-transitional, relatively migrant-rich lower-income neighbourhood. This contrasts to a relatively high-income neighbourhood, Guomao, in the Central Business District, which is considered in related research (Cao, 2019; Cao and Hickman, 2019a, 2019b). Tuqiao subway station was opened in December 2003 and is located on the Batong Line, which is also a Line 1 extension (Figure 15.1).

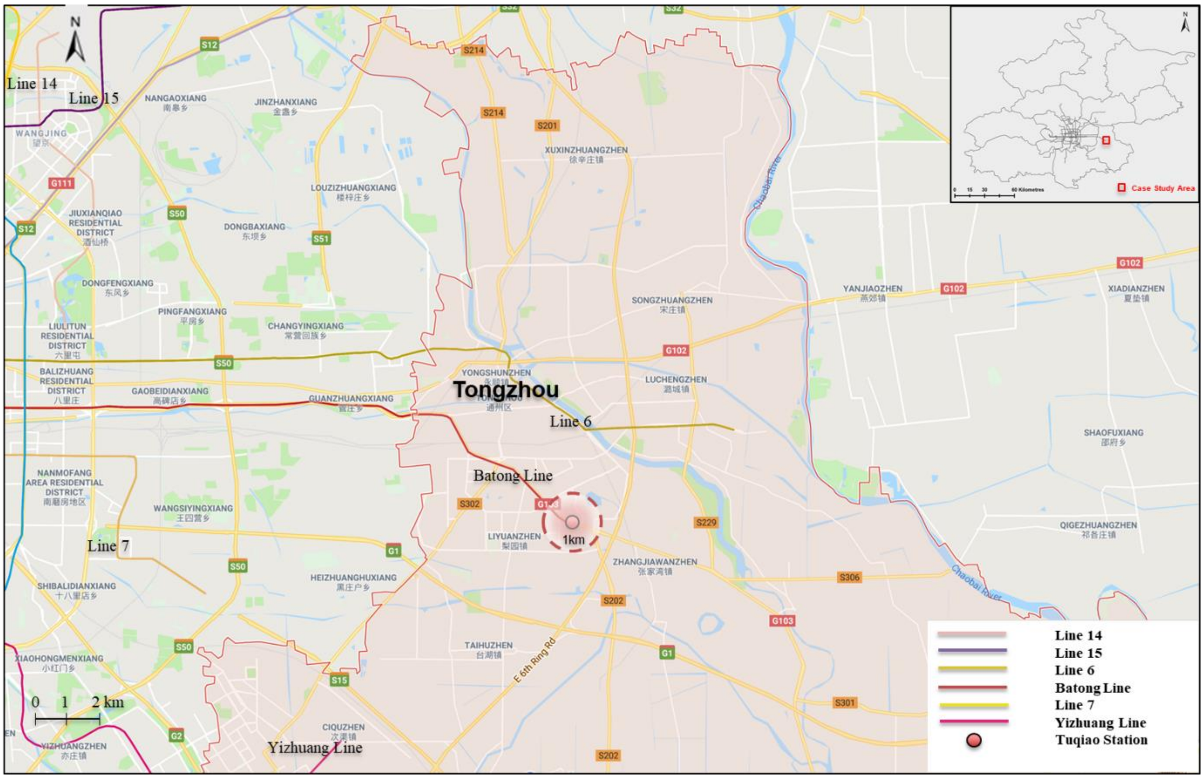

Figure 15.1 Case study of Tuqiao, showing Tuqiao subway and surrounding neighbourhood, East Beijing

(Source: Authors, using OSM Open Data License, 2018)

Figure 15.2 gives the theoretical framework for the analysis using the CA. Nussbaum's central human capabilities (Nussbaum, 2000, 2003, 2011) are modified and applied in the transport context (Cao, 2019; Cao and Hickman, 2019a, 2019b). The key concepts used from the CA are capabilities (an individual's real opportunities for travel and participation in activities) and functionings (the activities which they are currently performing). Capabilities are the most difficult to apply in transport, and we interpret this in this paper as perceived ideal accessibility. This is then compared to functionings, which are the realised activities (see further discussion in Hickman et al. 2017; Cao, 2019; Cao and Hickman, 2019a, 2019b). This distinction is very useful in transport planning, as often there are barriers to using accessibility through a particular public transport service, including cost of travel, education and skills, aspiration, etc. Examining the differences between real opportunities and realised activities can help us understand why particular population groups do not use public transport services despite living near to them. The following type of survey question is therefore used relative to different activities, such as access to employment, education and leisure.

a. Capabilities		***Your expected opportunities for travel and activities*** *(i.e. your wishes/expectations)*
	vs.	
b. Functionings		***Your everyday travel and activities*** *(i.e. your current situation)*

There are two main interpretations of transport-related social inequity in this context (Figure 15.2). Firstly, there are statistically significant differences between capabilities (i.e. the difference between a and a’) and functionings (i.e. the difference between b and b’) respectively, across the various socio-demographic characteristics of individuals. Secondly, the distribution of the difference between capabilities and functionings is regarded as a form of travel inequity (i.e. the difference between a minus b, and a’ minus b’) – if individuals have differences between their perceived ideal accessibility and realised mobility, then this represents a form of travel inequity.

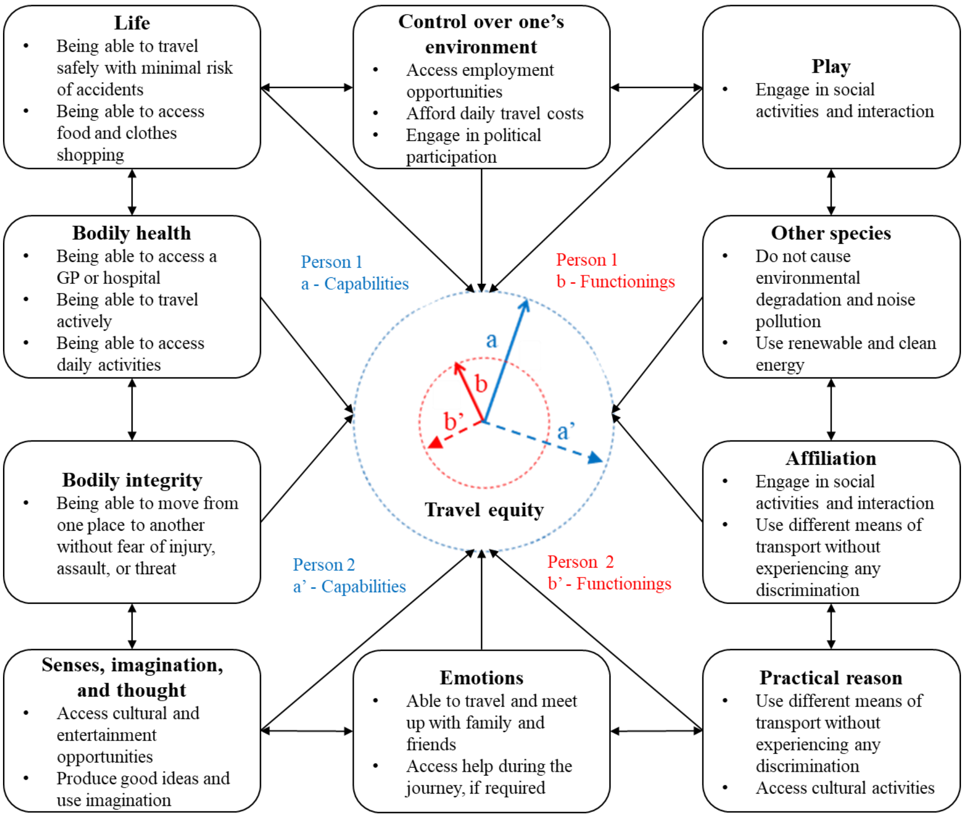

Figure 15.2 Research framework of capabilities and functionings (Cao, 2019)

The data used in this study was collected in 2016 with face-to-face interviews in Tuqiao, with 622 valid responses (Cao, 2019). We employed a simple random sampling approach to select (Fink, 2003; Valliant et al., 2013) and interview participants who were walking either near the station or in the communities within the station catchment area. Additionally, we also used a systematic sampling approach to select households (Fink, 2003; Pfeffermann and Rao, 2009) and carry out interviews in the communities within the station catchment area. All the respondents lived in Tuqiao, within a 1km radius of the station catchment area, and therefore had easy access to the Batong Line through Tuqiao subway station. Descriptions of the data variables are provided in Table 15.1.

Table 15.1 Descriptions of data 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)
Huk	Hukou status	1(Beijing hukou holders); 0(otherwise)
Inp	Incumbent population	1(moved to the area before the Tuqiao Underground station was opened); 0(otherwise)
Pmi	Personal monthly income	Monthly personal gross income in Chinese Yuan (¥): 1(<1,000); 2(1,000-2,000); 3(2,001-6,000); 4(6,001-10,000); 5(10,001-20,000); 6(20,001-30,000); 7(>30,000)
Cao	Car ownership	1(yes); 0(otherwise)
Capabilities & Functionings		
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	N/A
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_respect and 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	N/A

Note:
1. C&F = Capabilities and Functionings.
2. 'Not applicable' responses in the survey research are treated as missing values in statistical terms. Therefore, the sample size used in the analysis is 622.

3. METHOD

Different approaches to measuring transport-related social inequity were tested, including the CA and statistical F-test to explore differences across population groups, and an additional six approaches, namely the Gini coefficient, the Atkinson index, the Palma ratio, the Pietra ratio, the Schutz coefficient and the Theil index. The same case study and dataset were used with the different approaches and more detailed explanations of the methods and formulae are provided below.

3.1 Capabilities Approach and F-test

The Capabilities Approach and F-test (Blackorby et al., 1981; Foster and Shneyerov, 1996) is adapted from a study by Lorgelly et al. (2008), who used a similar approach to test their findings regarding inequalities in individual capabilities in order to understand the patterns and causes of enduring poor health among various groups of people in Glasgow. In the transport and context, it is assumed that differences in capabilities, functionings and the distance between these are all forms of social inequity, hence we are interested in the value of the variability in the numerator of the F-statistic (see Equation 1). A higher F value gives an indication of greater transport-related social inequity across population groups.

$$F = \frac{\sum_{i=1}^{\mu} n_i \, (\bar{Y}_i - \bar{Y})^2 \, / \, (\mu - 1)}{\sum_{i=1}^{\mu} \sum_{j=1}^{n_i} n_i \, (Y_{ij} - \bar{Y}_i)^2 \, / \, v} \tag{1}$$

Where:

- F: F value
- $\bar{Y}_i$: the sample mean in the ith group
- n_i: the number of observations in the ith group
- $\bar{Y}$: the overall mean of the sample size
- μ: the number of groups
- Y_{ij}: the jth observation in the ith out of μ groups
- n: the overall sample size
- v: degrees of freedom under the null hypothesis (i.e. n - μ)

3.2 Gini Coefficient (and Lorenz Curve)

The Gini index is a well-established approach, developed by the Italian statistician, sociologist and demographer Corrado Gini in 1912. It has conventionally been used to measure income inequality (Gini, 1912) (see Equation 2). This approach has already been applied as a statistical measure of inequality evaluation in the field of transport (see Delbosc and Currie, 2011c; van Wee and Geurs, 2011; Bhouri et al., 2016; Lucas et al., 2016; Guzman et al., 2017). In this context, a high Gini ratio (concave curve, see Figure 18.3 – Lorenz curve) indicates that people experienced high levels of overall transport-related social inequity. It has previously been applied in terms of functionings (i.e. realised mobility) rather than capabilities, and is useful for examining differences between neighbourhoods.

$$G = 1 - \sum_{m=1}^{n}(X_m - X_{m-1})\,(Y_m + Y_{m-1}) \quad (2)$$

Where:

- *G*: Gini coefficient ($G \in [0, 1]$)
- X_m: the cumulative proportion of the population variable, for m = 0, …, n, with $X_0 = 0$, $X_n = 1$
- Y_m: the cumulative proportion of the functionings variable, for m = 0, …, n, with $Y_0 = 0$, $Y_n = 1$

3.3 Atkinson Index

The Atkinson index was developed by the British economist Anthony Barnes Atkinson, who used it to measure income inequality (Atkinson, 1970) (see Equation 3). In our case, a high Atkinson parameter implies high levels of transport-related social equity across the respondents. This measurement is particularly helpful to determine which end of the overall functionings scores contributed most to the observed transport-related social inequity.

$$A = 1 - \left[\frac{1}{n} \sum_{m=1}^{n} \left[\frac{{x_m}^{1-e}}{\bar{u}}\right]^{\frac{1}{1-e}} \right] \quad (3)$$

Where:

- *A*: Atkinson parameter ($A \in [0, 1]$)
- *e*: inequality aversion parameter
- $\bar{u}$: the average overall functionings
- *m*: the m^{th} observation
- *n*: the overall sample size

3.4 Palma Ratio

The Palma ratio is also a measure of income inequality which is based on the work of Jose Gabriel Palma (Palma, 2011; Palma and Stiglitz, 2016). He argued that middle class incomes account for approximately half of gross national income, and are more stable, while the other half is unequally split between the richest (10 per cent) and the poorest (40 per cent), although their proportions vary considerably across countries. This approach has been applied in an empirical study to measure the inequality of the distribution of transport accessibility (Guzman and Oviedo, 2018). In our case, the Palma ratio is useful for measuring the differences between the top 10 per cent of individuals who experienced the lowest levels of transport-related social inequity and the bottom 40 per cent of people who suffered the most severe transport-related social inequity issues. The larger the Palma ratio, the higher the levels of transport-related social inequity. If *Pi* is the top *i* per cent of the population's share of overall functionings scores, then the formula for calculating the Palma ratio is as follows (Equation 4):

$$P = \frac{P_{i=10}}{P_{i=100} - P_{i=60}} \quad (4)$$

Where:

- *P*: Palma ratio

- *i*: the top i percentage of the overall functionings

3.5 Pietra Ratio

The Pietra ratio is an additional indicator for the Lorenz curve, as a measure of inequality for resource distribution across the population, which is particularly used in relation to health and income measurements. In this context, the Pietra ratio indicates that the proportion of overall functionings scores should have been transferred from those experiencing the least transport-related social inequity to those who suffered higher levels of transport-related social inequity in order to achieve a state of perfect equality. The Pietra ratio is shown below in Equation (5).

$$P' = \frac{1}{2} \sum_{m=1}^{n} \left| \frac{X_m}{X'} - \frac{Y_m}{Y'} \right| \quad (5)$$

Where:

- *P'*: Pietra ratio

- *n*: the number of quantiles

- X_m: the overall functionings in the m^{th} quantile

- *X'*: the sum of overall functionings for all quantiles

- Y_m: the size of the m^{th} person (i.e. the number of persons)

- *Y'*: the sum of all persons

3.6 Schutz Coefficient

The Schutz coefficient is also used as a measure of income inequality (Schutz, 1951) (Equation 6). In this context, it compares the overall functionings level of each person with the average overall functionings of the population, and then sums the absolute values of the differences between them, and views it as a proportion of the total functionings.

$$S = \sum_{m=1}^{n} |X - Y_m| Xn \quad (6)$$

Where:

- *S*: Schutz coefficient

- *n*: the overall sample size

- *X*: the average overall functionings of the population

- Y_m: the m^{th} individual overall functionings

3.7 Theil Index

The Theil index is another measure of economic inequality developed by a Dutch econometrician Henri Theil (Theil, 1967, 1972), which uses entropy measures based on statistical information theory (Equation 7). This index is also used to measure inequality in relation multi-group segregation (Reardon and Firebaugh, 2002). In this study, it provides a way to measure the discrepancy between the structure of the overall functionings across groups and the overall functionings across the same groups. In other words, a higher Theil value implies greater transport-related social inequity across groups.

$$T = \frac{1}{n}\sum_{m=1}^{n}\left(\frac{u_m}{\bar{u}} \times ln\frac{u_m}{\bar{u}}\right) \quad (7)$$

Where:

- T: Theil value ($T \in [0, 1]$)
- n: the overall sample size
- m: the m^{th} individual
- u_m: the overall functionings of individual m
- $\bar{u}$: the average overall functionings

4. MODELLING RESULTS AND COMMENTARY

4.1 Descriptive Statistics

A brief descriptive analysis of the responses is provided in Table 15.2. These samples show that there were fewer male respondents (40 per cent) than females (60 per cent). Most respondents were non-agricultural hukou[3] residents living in a transitional neighbourhood. This may be due to the rapid urbanisation process that has occurred in China since the 1990s (Liu et al., 2010) as well as emerging neoliberal urbanism (He and Wu, 2009). Furthermore, 33 per cent of residents living in the neighbourhood were migrants. There was a fairly normal age distribution. The majority of respondents (65 per cent) were aged between 25 and 44. In addition, more than 72 per cent of respondents' personal incomes were less than the average income of ¥7,706 per month. Moreover, 43 per cent of respondents did not own cars. Finally, it should be noted that our samples are most likely to be representative of relatively migrant-rich lower-income cohorts living in areas close to the station, with good accessibility to local transport services, and are not representative of all people residing in Beijing.

Table 15.2 Descriptive statistics

Individual characteristics	Survey sample (2016)

[3] Hukou refers to the household registration scheme used in China and is used to identify a person as resident in an area. Benefits such as education, health care and retirement pensions are particularly related to an urban local hukou, and migrants do not qualify for these, hence there is much inequity in the system.

		Count	Percentage
Gender	Male	248	39.9
	Female	374	60.1
Hukou	Non-agricultural residence	540	86.8
	Agricultural residence	82	13.2
	Beijing urban hukou holders	400	64.3
	Beijing agricultural hukou holders	16	2.6
	Non-Beijing urban hukou holders	140	22.5
	Non-Beijing agricultural hukou holders	66	10.6
Age	18-24	108	17.3
	25-34	230	37.0
	35-44	172	27.6
	45-54	62	10.0
	55-64	44	7.1
	65 or more	6	1.0
Personal income (RMB / month)	<1,000	76	12.2
	1,000-2,000	36	5.8
	2,001-6,000	336	54.0
	6,001-10,000	126	20.3
	10,001-20,000	42	6.8
	20,001-30,000	4	0.6
	>30,000	2	0.3
Car ownership	Yes	356	57.2
	No	266	42.8

4.2 Capabilities Approach (CA) F Test Results

The analysis examines whether capabilities and functionings show statistically significant differences across socio-demographic groups. It can be argued that conventional accessibility analysis overlooks the real opportunities (capabilities) and realised activities (functionings) elements of the CA as it examines a theoretical access to transport services, employment and other activities. All survey respondents live in the Tuqiao Underground station catchment area with good accessibility to the local transport service, but there are substantial differences in their actual travel behaviours according to socio-economic characteristics and individual abilities. Six social equity groupings are taken into consideration: gender, age, hukou, incumbent population, personal income and car ownership. Significant findings with regard to differences in transport-related social inequity are marked with asterisks (*) in Table 15.3.

With regards to gender, four of the capabilities categories (i.e. travel safety – accidents and violent assault, active travel, and respect and get help) have statistically significant differences (column 2, Table 18.3). The results show that males are more likely than females to be able to get help if they need it, whilst travelling across Beijing. Moreover, men again have higher levels of overall capabilities than women in terms of travel safety (accidents and violent assault) and active travel across Beijing. The findings imply a gendered inequality, meaning that females are more likely to experience transport-related safety issues, which is also in line with the existing literature illustrating how gender shapes mobility differently (Uteng and Cresswell, 2008; Uteng, 2009; Adeel et al., 2016), and that women's freedom of mobility to engage in daily life activities is more likely to be constrained (Shin, 2011; Turdalieva and Edling, 2017).

In terms of age, it was found that most categories display highly statistically significant differences. More specifically, in a relatively low-income neighbourhood, the results show that middle-aged people (35-54) have much higher scores for both capabilities and functionings than people who are over 55, and this is particularly noticeable for respondents aged over 65, in relation to activities such as “accessing grocery and clothes shopping”, “being able to travel safely (accidents and violent assault)”, “accessing training and education”, “creativity and imagination”, “seeking work opportunities” and “travel affordability”. The results imply that with advancing age, people seem to be more vulnerable when travelling and are struggling to adapt to rapid social change and unfavourable environmental and technological conditions (Mollenkopf et al., 1997), despite having good accessibility to local transport services. Some may also be experiencing a deterioration in physical function which could make travelling more problematic for them. However, people over 65 had the highest capabilities scores in relation to “accessing cultural activities” while respondents aged between 18 and 34 scored comparatively lower in this respect. A possible explanation for this may be that the younger generation are gradually losing interesting in going to concerts, live events and exhibitions, or at least have less time to do this. More in-depth interviews are required to explore the reasons for these findings.

The Chinese registration system known as hukou has a significant influence on transport and related inequity, as has been shown in the case of Beijing (Zhao and Howden-Chapman, 2010; Zhao and Li, 2016; Cao and Hickman, 2019b). It particularly affects commuting behaviour and access to jobs and housing, with migrants likely to be excluded from jobs, healthcare and educational resources. For Tuqiao, a relatively migrant-rich area, our results are in line with much of the previous literature, and reveal that migrants without a Beijing hukou experience transport-related social inequity and remain disadvantaged, i.e., they have much lower functionings-related scores compared to local Beijing residents with an urban hukou. In addition, immigrants’ (migrants in the context of Beijing) friendships tend to be largely within their own ethnic group, which could have the effect of constraining their accumulation of social capital and preventing them from exploring wider social networks (Schwanen et al., 2015). Migrants are also excluded from urban educational resources (Li and Zhao, 2018), and hence their children may find it difficult to gain entry to grammar schools due to not having Beijing hukou. The differences between migrants and local Beijing hukou holders will not be eliminated until further effective hukou reform policy is implemented in China. However, surprisingly, our findings appear to suggest that migrants did not face significant barriers to accessing jobs. This can be attributed, in the context of Tuqiao, to there being many lower-skilled migrants who are likely to have a casual working contract with their employers and be informally employed (Zhang et al., 2018), doing jobs such as delivering parcels (e.g. YTO Express, ZTO Express, SF Express,etc.) or food (e.g. Meituan, ele.me, etc.) due to the growth of e-commerce. This may allow them to eventually increase their job opportunities without being too restricted by their lack of hukou status, but of course the skill and pay levels will remain low.

In terms of the differences between incumbent residents and newcomers, it was found that although the travel equity gaps between the two groups are similar, the incumbent population appeared to have higher capabilities and functionings scores than newcomers. This may be because most newcomers in Tuqiao are relatively low-income migrants, perhaps doing temporary low-skilled jobs, and do not have Beijing hukou. Thus, they may gain fewer benefits and lack access to opportunities and resources compared to incumbent residents.

Income has always been taken into account as a key indicator when measuring accessibility and transport-related social inequity especially between better- and worse-off groups (de Vasconcellos, 2005; Guzman and Oviedo, 2018), as lower-income groups and the most socially disadvantaged within society are more likely to experience transport disadvantage than their higher-income counterparts (Lucas, 2004, 2012). Not surprisingly, almost all categories of capabilities and functionings have statistically significant differences based on respondents' personal monthly incomes. For instance, higher-income groups (personal income > ¥30,000) had capabilities and functionings scores which were over 33 per cent higher than relatively low-income respondents (personal income between ¥1,000 and ¥6,000) in terms of travel affordability. This implies that the lower-income population may have to spend a much higher share of their income on transport or perhaps travel less due to the unaffordability of travel costs (Stokes and Lucas, 2011; Titheridge et al., 2014; Stokes, 2015). This may eventually cause people with lower incomes to have lower overall mobility levels and to miss out on opportunities to access key life activities, in contrast to higher-income cohorts. However, it should be noted that, in relation to "active travel", lower-income groups appeared to have much higher capabilities and functionings scores than higher-income cohorts. This finding can be attributed to lower-income groups travelling less and finding jobs in nearby areas. Thus, they may be able to walk or cycle which would incur lower travel costs than travelling by Underground or driving private vehicles. Higher-income groups are more likely to drive private vehicles.

Finally, with regards to car ownership, although the results show that only three indicators have statistically significant differences, people who drive private vehicles are more likely to be able to access training, seek a wider array of job opportunities and afford the cost of travelling, across Beijing. This may imply that having access to a car could make additional opportunities available to people, particularly in terms of job accessibility; thus, there is still transport-related social inequity between car owners and non-car owners, especially in a relatively low-income neighbourhood.

Table 15.3 Summary test statistics (F tests) for differences in individual transport-related social equity in Tuqiao, Beijing

Capabilities and Functionings	Gender	Age	Hukou	Incumbent population	Personal income	Car ownership
Life						
C_travel safety (accidents)	4.404*	3.369**	0.261	0.441	4.401***	0.712
F_travel safety (accidents)	0.097	3.929**	0.635	1.381	6.739***	2.532

C_access grocery/clothes shopping	0.227	6.693***	0.264	16.763***	5.222***	0.110
F_access grocery/clothes shopping	0.081	3.045**	4.116*	5.997*	1.463	1.713
Bodily health						
C_access hospitals	1.068	6.765***	1.692	22.658***	6.471***	1.675
F_access hospitals	0.262	1.554	3.024	5.089*	4.441***	0.023
C_active travel	3.660*	0.705	0.678	2.020	2.719*	2.820
F_active travel	3.158	3.025**	0.336	1.156	5.375***	1.114
Bodily integrity						
C_travel safety (violent assault)	15.346***	4.342***	0.147	4.972*	2.883**	1.667
F_travel safety (violent assault)	0.829	4.200***	0.115	2.359	3.801***	2.820
Senses, imagination, and thought						
C_access training and education	1.367	3.957**	1.835	2.253	3.638***	0.082
F_access training and education	0.385	8.095***	4.694*	0.054	2.425*	8.922**
C_creativity and imagination	0.702	6.373***	2.088	3.875*	11.458***	2.677
F_creativity and imagination	0.072	4.013***	0.001	1.917	13.364***	1.005
C_religious exercise	N/A					
F_religious exercise	N/A					
Emotions						
C_travel and visit family/friends	0.186	6.223***	0.000	18.680***	5.491***	0.359
F_travel and visit family/friends	1.496	1.772	5.103*	7.498**	3.265**	3.078
Practical reason						
C_access cultural activities	2.949	5.026***	0.014	12.925***	7.993***	0.591
F_access cultural activities	3.391	1.801	3.334	12.097***	2.655*	1.149
Affiliation						
C_respect and get help	3.926*	0.832	1.029	1.303	2.242*	0.190
F_respect and get help	0.737	1.964	0.033	0.285	3.541**	0.010
Other species						
C_against environmental degradation	2.686	0.997	0.340	0.592	0.896	0.167
F_against environmental degradation	0.509	2.201	4.672*	4.051*	5.200***	0.073
Play						
C_leisure and recreation	2.681	3.392**	0.201	0.910	3.809***	3.289
F_leisure and recreation	2.800	0.597	3.416	5.607*	1.219	1.713
Control over one's environment						
C_seek work opportunities	2.428	6.523***	0.078	1.829	5.375***	0.036
F_seek work opportunities	1.856	5.521***	0.008	0.952	1.556	9.327**
C_travel affordability	3.152	2.717*	1.158***	16.821***	8.171***	8.424**
F_travel affordability	3.336	2.964*	3.565*	5.483*	9.137***	0.144
C_political participation	N/A					
F_political participation	N/A					

(n= 622)
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 and further interpretation of the findings can be found in Cao (2019).

4.3 Wider Inequality Indices Results

In this research, we believe that effect sizes can be used to describe to what extent each of the different approaches can reflect transport equity issues. For example, in terms of functionings (i.e. realised mobility), effect sizes can be used rather than specifying a range of threshold values for each of the indices. There is some debate about whether it is still appropriate to use exactly the same threshold value drawn from the economics domain to measure and represent inequalities in the transport context, such as using the value of 0.4 derived from Gini coefficient (OECD, 2014, 2015). This is because there have been significant differences in the past few years between economic inequality and transport-related inequality and it is unlikely that thresholds will transfer well across topics and contexts (Banister, 2018).

A summary of results obtained using different evaluation approaches to measure individual transport-related social inequity in Tuqiao is provided in Table 15.4, showing two main aspects: 1) Effect sizes: how sensitive the approach is (see Hagenauer and Helbich, 2017) when it is used to examine transport equity issues; 2) Interpretation: how easily the results can be interpreted and understood in the transport equity domain.

The results reveal the different findings that can be used with the various approaches. The CA has the largest effect size, while the modelling results can be easily and clearly interpreted. The Palma ratio is useful for measuring the extreme differences between the top 10 per cent of individuals who experienced the lowest levels of transport-related social inequity and the bottom 40 per cent of people who suffered the most severe transport-related social inequity issues; it is also able to overcome the sensitivity to change in the middle of the functionings distribution (compared to the Gini coefficient (Figure 15.3) or Schutz coefficient, for example).

More specifically, for the CA in this context, the effect size indicates that there is a large difference in F value scores, which means that most residents living in Tuqiao are more likely to experience high levels of transport-related social inequity in terms of functionings. The Gini coefficient produces a low effect size, with a score of 0.078. The Lorenz curve (Fig. 15.3) implies that Y per cent of aggregated functionings' scores for X per cent of residents in Tuqiao experienced severe transport-related social inequity issues. Furthermore, the Atkinson parameter, the Pietra ratio, the Schutz coefficient and the Theil index all indicate a relatively small effect size, meaning that most respondents do not appear to experience high levels of transport-related social inequity, at least in this case. Finally, the Palma ratio is 0.352, indicating a medium effect. This means that the top 10 per cent of individuals who experienced the lowest levels of transport-related social inequity have approximately 0.4 times higher overall functionings scores than the bottom 40 per cent of people who suffered the most severe transport-related social inequity.

Table 15.4: Summary of results using different evaluation tools to assess of individual transport-related social inequity in Tuqiao, Beijing

Measurement approach	Ratio / Parameter	Effect size[a]	Interpretation[b]
Capabilities Approach	F values (see Table 3)	3	3
Gini coefficient	0.078	1	2
Atkinson index	0.007	1	1
Palma ratio	0.352	2	3
Pietra ratio	0.055	1	1~2
Schutz coefficient	0.155	1	1
Theil index	0.014	1	1

(n = 622)

Note: a. Effect sizes: 1 - a small effect; 2 - a medium effect; 3 - a large effect.

b. Interpretation: 1 - not easy; 2 - neutral; 3 - easy.

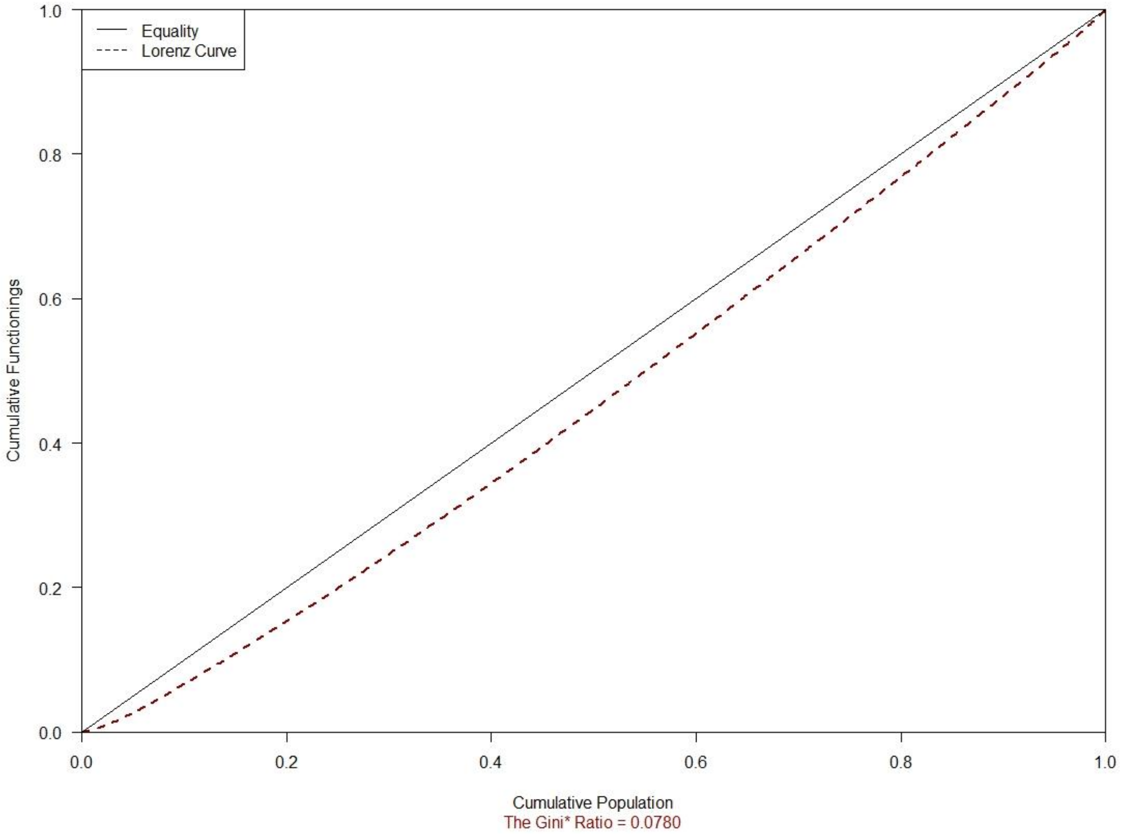

Figure 15.3 Lorenz curve for transport-related social inequity (Functionings) in Tuqiao

5. CONCLUSIONS

This chapter has not only used an emerging and innovative approach, the CA, but has also used six other measures of inequality to examine transport-related social inequity, at the individual level, for residents living in the subway station catchment area of Tuqiao, Beijing. It has also examined how different inequality tools can be used in assessing transport-related equity issues.

There are different approaches available, including the CA, the Gini coefficient, the Atkinson index, the Palma ratio, the Pietra ratio, the Schutz coefficient and the Theil index, which can be applied in different circumstances. Based on our findings, it is suggested that the CA is useful in assessing transport-related inequalities where there are significant barriers to the take up of accessibility, for example where there are high levels of disadvantaged groups and disaggregated analysis can be undertaken. The Palma ratio appears to have a larger effect when measuring transport-related social inequity than the Gini coefficient (Guzman and Oviedo, 2018) and the other inequality tools in this case. Furthermore, based on our findings, it is argued that most income inequality approaches adapted from econometrics may be more appropriate for measuring transport-related social inequity between different regions, cities or countries (Delbosc and Currie, 2011c; Lucas et al., 2016), or within the same area but at different points in time (Guzman and Oviedo, 2018), and perhaps in the case of people who have vastly different levels of socio- or spatial-inequity in terms of transport accessibility (Guzman et al., 2017; Jang et al., 2017), rather than for measuring a single neighbourhood, at least in our case.

The analysis makes several key contributions to the existing literature and methodology. First, this study provides new evidence on the potential limitations of investigating the effects of a relatively migrant-rich (i.e. without Beijing local hukou) lower-income neighbourhood, emphasising that hukou still plays a significant role as a barrier to transport equity (Zhao and Howden-Chapman, 2010). Second, gendered transport inequality is clearly evident (Uteng, 2009; Adeel et al., 2016), not only in a relatively wealthy neighbourhood (Cao and Hickman, 2019b), but also in a lower-income area. Not surprisingly, higher-income cohorts had both higher levels of capabilities and functionings scores compared to their less well-off counterparts, meaning that lower-income groups are still more likely to be socially disadvantaged (Lucas, 2004, 2012). Moreover, owning a car appeared to have little effect on the residents living in a wealthy neighbourhood (Cao and Hickman, 2019b), but it was significant for people residing in a lower-income area, as non-car owners experienced constraints in terms of the job and educational opportunities and resources available to them, which may in turn prevent them from realising their human capital potential, as well as having an adverse effect on their development and quality of achievements, ultimately exacerbating social inequity issues (Banister, 2018). Finally, in terms of the contribution to the methodology, six different income inequality tools were adapted and applied in the transport context, which enabled us to evaluate the effectiveness of the measurements, compare each of the tools and then justify which one had the largest effect when measuring individual transport-related social inequity.

In terms of policy implications relating to the transport equity domain, we suggest that politicians and transport planners should take the context-specific situations into account and then carefully select an appropriate measurement tool in order to evaluate the impacts of transport-related social equity rather than simply using a conventional inequality tool which may not capture local, individual social inequity issues very effectively. In addition, based on our analysis (e.g. comparisons between Gini coefficient and Palma ratio), it would seem that political intervention should focus on the bottom 40 per cent of people who are most severely affected by transport-related social inequity, through long-term social investment, rather than simply subsidising transport fares or giving discounts for all those living in Beijing. In particular, efforts should be made to help migrants who primarily live and work in Beijing in order to facilitate accessibility to a wide range of key life activities, and offer them more opportunities and resources to address the inequality issues that they face. In addition, in a general sense, the CA can be seen as an appropriate tool with which to evaluate transport-related social inequity, and therefore it should be added to the existing inequality measurement tools for use in the transport context. Finally, we argue that to what extent politicians or transport planners can use appropriate management tools to address transport-related social inequalities will have a significant effect on the progress that can be made in this area.

ACKNOWLEDGEMENTS

This research is partly funded by the National Natural Science Foundation of China (Project No. 51808392). The authors would like to extend their appreciation to Dr Andy Ho (LSE) for his mathematics contributions and Dr Daniel Oviedo (UCL) for sharing his opinions on the discussion of the Palma ratio. Thanks also to the reviewers for their useful feedback on the initial manuscript.

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