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ASSESSING INEQUALITY IN TRAVEL TIME AND DISTANCE CONSUMPTION IN CÓRDOBA CITY, ARGENTINA

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ABSTRACT

While inequalities in travel patterns have increasingly been quantified in Latin American cities, analysis regarding the disparity of distributions in travel time and distance among the population is a new aspect of this research. This paper uses traditional economic measures of inequality - the Gini, Theil, and Atkinson index - to understand the degree of inequality in transport consumption in Córdoba city. We propose the variables Daily Travel Distance (DTD) and Daily Travel Time (DTT) to be evaluated for two levels of analysis: household and individuals.

Our results show that DTT is more sensitive to the value of aversion to inequality parameter (ε) - the Atkinson index - than DTD for both units of analysis (household and individuals). The Atkinson measure appears to be a better measure than Gini or Theil.

Inequalities in transport patterns observed in Córdoba are lower than values observed in bigger cities such as São Paulo or Rio de Janeiro (Brazil). However, Córdoba has a similar proportion of persons reporting no trips (30.6%).

Household immobility (8.7%) appears to be a more adequate measure than individual immobility since differences between income groups in the population are more evident using household as a unit of analysis.

Keywords: Equity; Inequality valuations; Urban mobility

INTRODUCTION

Understanding differences in travel patterns is important for setting transport policies and transit system operations focused on equality. This paper presents a new approach to assess equity in daily travel time and distance consumption. We propose the use of traditional inequality measures (such as the Gini, Theil, and Atkinson index) to estimate the degree of inequality in terms of travel time and distance in Córdoba city (Argentina). Using household travel survey data, it is possible to compute Daily Travel Distance (DTD) and Daily Travel Time (DTT) for two levels of analysis, household and individuals.

BACKGROUND

Daily mobility patterns in developing countries.

Recently, new information regarding daily mobility patterns in Latin American cities has become available. Several mobility reports (IPEA, 2011; PTUMA, 2011; CAF, 2010; Vasconcellos, 2010; CENTRAL, 2005) and academic research studies were conducted (Motte-Baumvol and Nassi, 2012; Bocarejo and Oviedo, 2012; Vasconcellos, 2005) focusing on issues such as immobility, socioeconomic characterization of travel behavior, affordability, and accessibility for poor families. Here, we focus our review on daily mobility patterns in Latin American cities compared with other countries and regions to understand the characteristics of travel behavior in this region.

According to Motte-Baumvol and Nassi (2012), mobility reports in Rio de Janeiro (Brazil) indicate important differences in travel behavior compared to in developing countries. The authors show that there are higher levels of immobility. A total of 46% of residents in the Rio de Janeiro metropolitan area made no trips on the day of the survey; in European countries, this value is between 10% and 26%, depending on the country). Motte-Baumvol and Nassi explains that immobility is not only related to income inequality, in fact *"...poverty as expressed by income is not a factor capable of directly explaining high levels of immobility..."*. They state that characteristics of individuals and their households, such as employment status and level of education, are the principal determinants of immobility. Of course, these variables are also related to poverty.

Motte-Baumvol and Nassi (2012) also explain that the average trips rates in Rio (1.77 [trips/person/day]) are lower than in France (3.50 [trips/person/day]) or the United States (4.00 [trips/person/day]). These values are similar to average trips rates in others Latin American cities, i.e., near 2.0 [trips/person/day], and are only slightly higher than those observed in Asian cities (CAF, 2010).

Another characteristic of daily mobility in Latin American cities is the share of trips made by public transport. In São Paulo, 33% (Vasconcellos, 2005) and 46% in Rio (CENTRAL, 2005) of trips are made by public transit. In Buenos Aires, this proportion is 40% (CAF, 2010). Despite this modal share, there is a high proportion of the population that lives in socially excluded conditions with no access to employment or services (see Bocarejo and Oviedo, 2012; Garreton, 2011; Gutierrez, 2005).

Diaz Olvera et al. (2008) studied six African Sub-Saharan cities in which levels of poverty are extremely high and the transit supply is low and found that a significant portion of the population has no other choice than to walk (walk mode represents 42 to 74% of trips), leading to a completely different modal share. Compared with Latin American cities, public transport accounts for a lower modal share, representing only 3 to 31% of trips, depending on the city. According to Diaz Olvera et al. (2008), these African cities show higher trip rates than Latin American cities (2.7 to 4.4 [trips/person/day]). However, it is important to note that these results may be affected by the survey method. Motte-Baumvol and Nassi (2012) explain that in Rio de Janeiro, the household travel survey does not count trips of less than 300 meters, while travel surveys in Paris counts all trips over 1 minute long and in African city surveys, all trips were included (Diaz Olvera et al., 2008).

What about inequalities in daily mobility?

Up to this point, we have discussed average values and rates; however, to understand the degree of inequality in daily mobility, it is important to observe how these values vary across different social groups. Based on data from the 1997 household travel survey in São Paulo city, Brazil, Vasconcellos (2005) analyzed how travel times, dynamic distance,[1] energy use, fuel use, pollution, and accidents vary with family income. The author employed highest/lowest income class ratio analysis and found that people in the highest income group use cars intensively, spending 3.3 times more time in transport and traveling 8.4 times larger distances than individuals in the low-income group.

The highest/lowest income class ratio is a simple measure of dispersion that only considers extreme values of a distribution. Other studies attempt to use inequality measures to assess equity in transportation; for example, Delbosc and Currie (2011) studied the equity of opportunity of transit supply in Melbourne (Australia). They used Lorenz curves and the Gini coefficient to compare the distribution of public transport supply across the population. Their results showed that 70% of the population in Melbourne shares only 19% of the transit supply. This means that the distribution of transit service is concentrated as indicated by the high values of the Gini coefficient (0.68).

Diaz Olvera et al. (2004) and Paulo (2006) used several inequality measures, such as standard deviation, coefficient of variation, and Gini coefficient to assess dispersion in the number of daily trips, daily travel distance, and travel time budget in Lyon, France. Diaz Olvera et al. (2004) found that daily travel distance distribution is a more concentrated variable (G = 0.56) than daily travel time (G = 0.43). Both studies highlight that in Lyon, the inequalities of travel behavior are more related to car availability than to socioeconomic level of the individual. This means that when individuals have regular and autonomous access to a car, they use it in the same manner, irrespective of their income level

These studies have in common that they treat inequalities in a quantitative manner, using inequalities measure to assess the dispersion degree of a variable (for example transport

[1] According to author “dynamic distance” represents the space consumed. It is computed as the aerial distance between the centers of origin and destination zones, magnified by a factor of 1.3 and by the area occupied per person, per mode.

supply, daily travel distance, or time). In this paper, we propose that a measure of inequality should be included in household travel survey data.

CONCEPTUAL DISCUSSION

From economic inequality to urban mobility inequality

In economics, the inequality concept focuses on the measurement of disparity of income distribution in aggregate form. Income is a personal/household attribute that represents welfare, but it is a simplification since welfare is a more complex concept. In the same way, income is a simplification of the household income concept, i.e. there are some situations in which a person may receive different types of compensation (e.g. poor workers that receives social security or worker's compensation), or where the remuneration is given in goods and not in money. For a complete explanation regarding the income concept see, for example, Campano and Salvattore (2006).

Cowell (2009) suggests that economists use income as main variable to assess economic inequality because it is measurable and comparable for different people. Additionally, there is a significant amount of data available regarding income through census and survey data.

Foster and Sen (1997) classified inequality measures as: *objective* and *normative* measures. The first attempts to capture the extent of inequality in an objective sense, typically with some statistical measure of relative variation of income (e.g. Gini coefficient). The second approach attempts to measure inequality in terms of some normative notion of social welfare, so that a higher degree of inequality corresponds to a lower level of social welfare for a given total of income. This means that in a normative approach, the problem of measurement is more related to ethical evaluation. However, in some way, all inequality measures are related to normative concern; in fact, any of these indices (normative or objective) attempts to measure how "good" the distribution of a resource in a society is, implying an ethical judgment (Foster and Sen, 1997).

While inequalities in urban mobility can be treated in the same manner as economic inequality, some concepts must be discussed.

First, is necessary to define what type of inequality we are attempting to measure. We are interested in assessing the actual situation of trips in the city, i.e., the way that people use the available space to reach activities. Here, is important to clarify the link between transportation inequalities and economic inequalities. Since income is a "scarce" resource in society that is distributed among the population, in the case of transportation it is possible to think that the "scarce" resource is the urban space available that allows individuals to reach some activities. Thus, Daily Travel Distance (DTD) and Daily Travel Time (DTT) can be used to represent the degree of consumption of space that a person (or household) have.

The variables DTD and DTT are related to the amount of "mobility" that a person (or household) have; in fact, there are several studies showing that the wealthiest groups of a population spend more time and distance in travel than poor groups (Motte-Baumvol and Nassi, 2012; IPEA, 2011; CAF, 2010; Vasconcellos, 2010; 2005). These inequalities in the consumption of travel time and distance are, of course, more important in developing countries than in European or North American countries since there is an important proportion of population that has no access to cars and more people living under poverty conditions who cannot afford extensive travel (Estupiñán et al., 2007; Venter and Behrens, 2005; World Bank, 2002). Another important consideration is that information about travel time and distance are commonly available in cities that have conducted household travel surveys. Thus, it seems reasonable to use the DTD or DTT as variables for assessing transport "consumption" inequality in a city.

It is important to note that we are not attempting to measure the disparity in terms of accessibility or potential mobility; we are interested in assessing inequalities in the actual distribution of travel distance and time.

Transport inequality and objective measures.

Applying *objective* measures to assess inequalities in DTD and DTT variables is not difficult. According to Medeiros (2012), objective measures can be used in any quantitative and measurable variable and not just for income distribution. In this paper, we use the following objective measures: Gini coefficient and Theil index.

Transport inequality and normative measures

In contrast, for *normative* measures we must establish what a "right" allocation of resources is. In this paper, we propose the Atkinson index as a normative measure for assessing inequalities in DTD and DTT consumption among a population. The Atkinson index is, in fact, a family of values since it depends on the value of the aversion to inequality parameter (ε) (see Eq. 6). In economics, the aversion to inequality parameter reflects the relative sensitivity to redistribution from the "rich" to the "poor". A higher the value of ε indicates a more sensitive index to changes at the bottom of the distribution.

As we discussed earlier, we assumed in this study that the amount of distance (DTD) or time traveled in a day (DTT) reflects the degree of urban space consumption. In terms of Atkinson's index, this assumption means: 1) that a person who travels longer distances or for a greater time has higher welfare (see Eq. 1) and 2) it is accepted that a society could have the same welfare if the resources of distance and time are equally distributed (see Eq. 2).

As a normative measure, Atkinson's index is based on a utility function ($U(y)$) that explicitly explains how income and aversion to inequality parameter affects the welfare level (or utility) perceived by a person (Eq. 1). In our study, income (y) is replaced by DTD and DTT variables, which accepts the assumption that a person who consumes a greater quantity of distance or time has a higher welfare level (or utility).

$$U(y) = \frac{y^{1-\varepsilon} - 1}{1-\varepsilon} \qquad (1)$$

The second aspect can be explained based on the fundamental equation that allows understanding of the meaning of the Atkinson measure (Eq. 2) (Atkinson, 1970; Cowell, 2009). Atkinson uses the concept of *Equally Distributed Equivalent level of income* (y_{EDE}), i.e., *"...the level of income per head which if equally distributed would give the same level of social welfare as the present distribution..."* (Atkinson, 1970).

$$A_{\varepsilon} = 1 - \frac{y_{EDE}}{\bar{y}} \qquad (2)$$

In our case, we are considering distance and time and, in terms of Atkinson measure, this means that there is an *Equally Distributed Equivalent amount of daily travel distance (or time)* that gives the same level of welfare representing the actual distribution.

LIMITATIONS

In the previous section, we explained that, in terms of Atkinson index, a person who travels more (distance or time) has higher levels of welfare. This is clearly a simplification since we are not considering the spatial location of activities. For example, a household located in a suburbia that "spends" a large amount of distance in travel does not necessarily have higher well-being than a household that travel less because it is centrally located. From this point of view, the best method for quantifying transport inequality may be using the accessibility concept, but this beyond the scope of this work since we have no information concerning activity locations in Córdoba city.

Another important limitation of this research is that the study area is limited to the urban area of Córdoba city; this means that trips with their origins or destinations out of the urban area were not computed here.

URBAN MOBILITY IN CÓRDOBA CITY

Córdoba is the second largest city in Argentina with 1.3 million inhabitants. It is a monocentric city with high density in the central area (Figure 1). Córdoba has an important supply of public transit service by bus and trolley resulting in a radial transit network covering more than 95% of the urbanized area of the city. However, during rush hour, the transit service has low level of service because buses are crowded and the lack exclusive lanes and experience high traffic levels, reducing average commercial speed and headways.

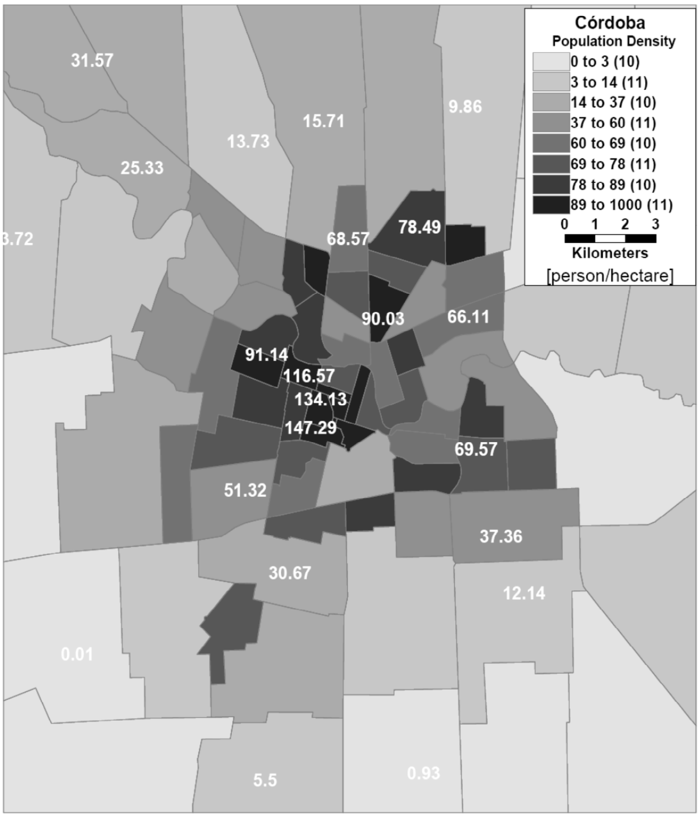

Figure 1 - Population density (inhabitants/hectare) in Córdoba city, Argentina. Based on 2008 Córdoba Census data.

Table I shows mobility indicators in Córdoba. Compared with other Latin American cities, Córdoba has similar mobility patterns, with a high proportion of immobile individuals (30.6%) -people that reported no trips on the day of the survey-, low average trip rates (1.64 [trips/person/day]), and important disparities in travel time and distance consumption between high/low socioeconomic groups. Comparing personal trip rates values, it seems that there is no important difference between "high" and "low" socioeconomic level (1.86 [trips/person/day] versus 1.32 [trips/person/day]), and all groups shows similar average trip duration (about 25 [minutes]). However, Table I also shows that the wealthiest group travels with higher speed, i.e. 1.44 times faster than the poor group, and that there is an important difference in immobility values.

These differences in speed and immobility values lead to major disparities in time and distance consumptions. As shown in Table I, households classified to have a high socioeconomic level spend 1.95 times more time traveling than poor households (166 [minutes] versus 85 [minutes]). For daily travel distance, the high/low rate is 2.81 (41.4 [km] versus 14.7 [km]).

Travel time budget for individuals appears to correlate with the values reported by Zahavi, i.e., people spent 1 hour each day traveling when aggregate values are considered (Zahavi, 1974; Schafer, 2000). On the other hand, for household level of analysis, both travel time and daily distance budgets seem to be lower in Córdoba than in São Paulo (Vasconcellos et al., 2011; CAF, 2010).

Table I – Mobility indicators in Córdoba city. Expanded data. Source: own elaboration based on PTUMA (2011).

Mobility indicators	Socioeconomic Level Index of Households (INSE)					Vehicle ownership		Total
	High	*Medium high*	*Medium*	*Medium low*	*Low*	*Households without car*	*Households with car*	
Households Immobility (% households without trips)	3.8%	4.8%	7.7%	13.4%	28.4%	11.2%	5.5%	8.7%
Individuals Immobility (% persons that make no trips)	27.3%	27.9%	31.8%	34.8%	39.9%	32.5%	28.5%	30.6%
Households Trip Rates (all households)	6.75	5.88	4.88	4.36	3.48	4.45	6.46	5.33
Households Trip Rates (only households with trips)	7.02	6.18	5.29	5.04	4.87	5.02	6.84	5.84
Person Trip Rates (all persons)	1.86	1.70	1.56	1.50	1.32	1.51	1.78	1.64
Person Trip Rates (only travelers)	2.56	2.36	2.29	2.30	2.20	2.24	2.49	2.37
Households Daily Travel Time (all households) [minutes]	166	157	134	116	85	122	163	140
Households Daily Travel Time (only households with trips) [minutes]	172	165	145	134	119	137	172	153
Persons Daily Travel Time (all persons) [minutes]	45.7	45.4	42.8	39.7	32.2	41.4	44.8	43.1
Persons Daily Travel Time (only travelers) [minutes]	62.9	62.9	62.8	61.0	53.6	61.4	62.7	62.1
Average Trip Duration [minutes]	24.6	26.7	27.4	26.5	24.4	27.4	25.2	26.2
Households Daily Travel Distance (all households) [km]	41.4	33.3	26.2	22.0	14.7	22.7	38.2	29.4
Households Daily Travel Distance (only households with trips) [km]	43.1	35.0	28.4	25.4	20.6	25.6	40.4	32.3
Persons Daily Travel Distance (all persons) [km]	11.4	9.6	8.4	7.6	5.6	7.7	10.5	9.1
Persons Daily Travel Distance (only travelers) [km]	15.7	13.3	12.3	11.6	9.3	11.4	14.7	13.1
Average Trip Length [km]	6.1	5.7	5.4	5.0	4.2	5.1	5.9	5.5
Average Travel Speed [Km/h]	15.0	12.7	11.7	11.4	10.4	11.2	14.1	12.6

METHODOLOGY

Data and studied area

As a data source, we used the 2009 Córdoba Household Travel Survey that was conducted under the Metropolitan Area Urban Transport Project in Argentina (PTUMA, 2011), a World Bank project for medium-size metropolitan areas. Travel distance data was computed as linear distance between centroids of the O-D transport zones declared in the survey. Based on the fact that in the survey only takes into account trips over 400 meters long, we assume that trips with their origins and destinations in the same zone are 500 meters long, which is a reasonable value since this is the equivalent distance to a radius of a circle with the same area of the central zones of transport.

The survey was administered to all household members using four questionnaires: the first and second focus on the basic characteristics of a household (address location, telephone, number of members, etc.) and socioeconomic information of the members (occupation, education, age, sex, etc). The third form asks about trip information (origin, destination, time, mode, fare, etc). The last part of the survey refers to a qualitative opinion of the public transport system. The sample included 2800 households in the Córdoba Metropolitan Region, of which 1936 are in Córdoba City.

This research is limited only to the urban area of Córdoba. Trips with their origins or destinations outside of the city limits were not considered here.

Inequality measures

Gini coefficient

There are different methods for defining the Gini coefficient (G) (see Cowell, 2009). Perhaps the easiest definition is: the average difference between all possible pairs of “quantities” in the population. A definition of G is given in Eq. 3:

$$G = \frac{1}{2n^2\bar{y}} \sum_{i=1}^{n} \sum_{j=1}^{n} \left| y_i - y_j \right| \qquad (3)$$

Note that ***y*** represents the variable under evaluation, i.e. in traditional inequality distribution analysis ***y*** is the income, but in this paper ***y*** represents the Daily Travel Distance (DTD) or Daily Travel Time (DTT). Finally, ***n*** is the number of persons or households in the study area.

If all quartiles contain the same number of persons, Eq. (3) can be simplified to Eq. (4) (Medeiros, 2012):

$$G = 1 - \frac{1}{n} \sum_{i=1}^{n} (y_i - y_{i-1})$$

(4)

The Gini coefficient varies between 0 (perfect equality situation, "the same for all") and 1 (maximal inequality situation, "only one person have all resources of the society").

T-Theil index

The T-Theil measure is an objective measure based on information theory developed by Theil in 1967. This index can be computed based on Eq. 5 as follows (Cowell, 2009):

$$T = \frac{1}{n}\sum_{i=1}^{n}\frac{y_i}{\bar{y}}\ln\left(\frac{y_i}{\bar{y}}\right) \qquad (5)$$

Theil index can vary between zero (no inequality situation) and **ln*n*** as the maximum value (total inequality).

Atkinson index

Following Cowell (2009), Atkinson inequality index can be defined as Eq. 6:

$$A_{\varepsilon} = 1 - \left[\frac{1}{n}\sum_{i=1}^{n}\left(\frac{y_i}{\bar{y}}\right)^{1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}} \qquad (6)$$

where (ε) represents the aversion to inequality parameter.

RESULTS

First we plot household daily travel time and distance frequency distributions. Figures 2 and 3 show two distributions, one considering all households (dashed line) and the other taking into account only households reporting at least one trip in the survey (black line). This allows us to understand the effect of immobility (households that make no trips).

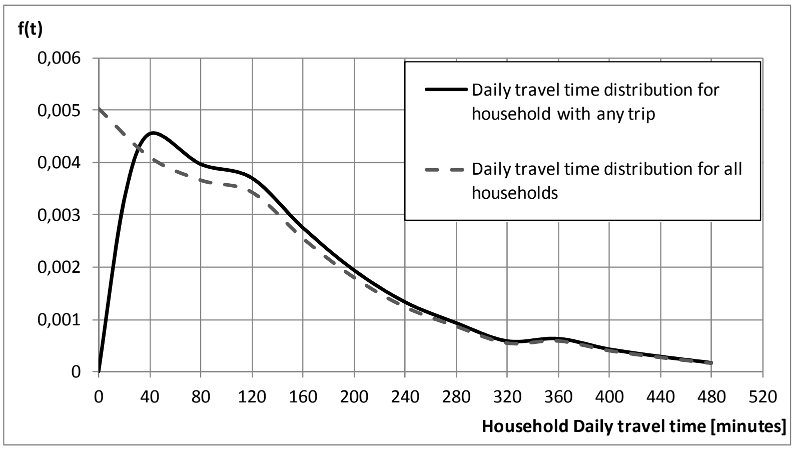

Figure 2 – Households daily travel time frequency distributions. Expanded data.

Figures 2 and 3 show that when only households that made trips are considered, the curves have a single mode and both are right-hand skewed distributions.

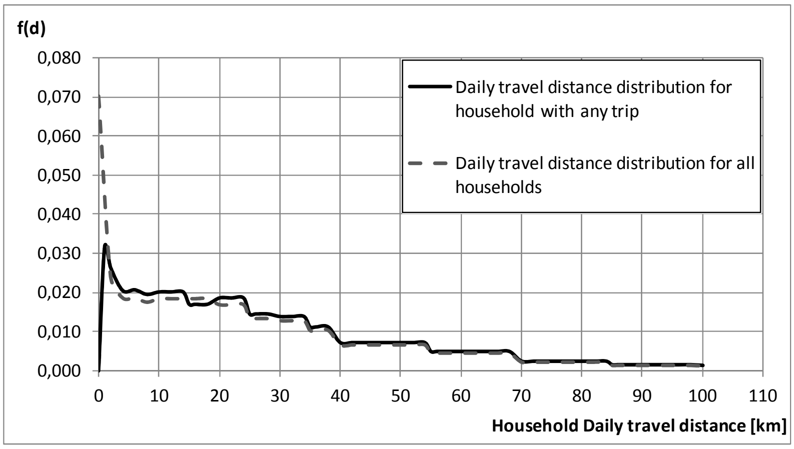

Figure 3 – Households daily travel distance frequency distributions. Expanded data.

Table II – Descriptive statistics of Daily Travel Distance and Daily Travel Time distributions. Sample values.

	Daily Travel Distance [km]		Daily Travel Time [minutes]	
	Households	Individuals	Households	Individuals
Mean	30.4	12.8	144.0	60.9
Median	22.4	10.2	120.0	50.0
Mode	0	0	0	60
Standard Deviation	30.4	12.1	126.7	45.4
Variance	924.6	145.9	16,044.8	2,056.7
Kurtosis	4.4	3.3	3.1	2.7
Coefficient of Variation	1.00	0.94	0.87	0.74
Minimum value	0	0	0	0
Maximum value	229	102	870	335
Cases (survey sample)	1,927	4,583	1,927	4,583

In Table II, Daily Travel Distance (DTD) and Time (DTT) distributions are characterized for both units of analysis, households and persons. Descriptive statistics shows that DTD distribution is more dispersed with higher coefficient of variation.

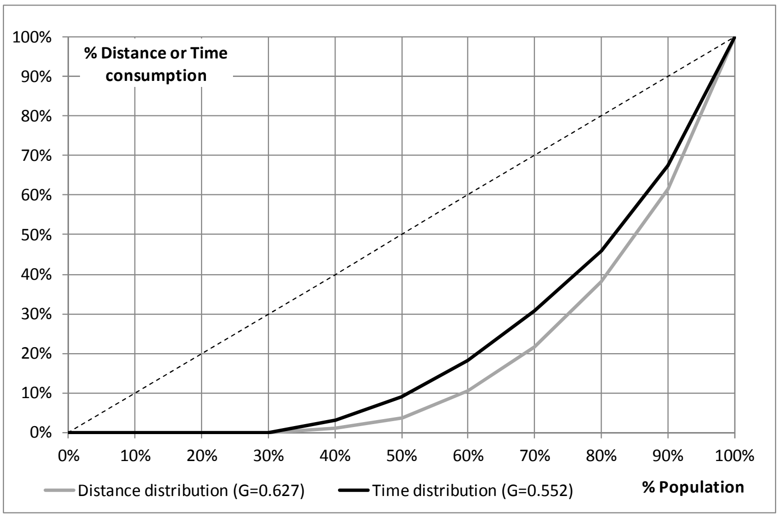

Figure 4 – Lorenz curves of individual daily travel time and distance distributions. Expanded data.

In economics, Lorenz curves are graphical representations of the cumulative distribution function of wealth across a population (Medeiros, 2012), where a dashed line represents a population of perfectly equitable income distribution and a solid curved line represents a real distribution of some quantity of wealth. These curves are typically applied to income distribution (the most common measure of wealth), but it can also be useful to any quantity that can be cumulated across a population. In this research, we plot Lorenz curves of daily travel time (DTT) and distance (DTD) distributions for both individuals (Figure 4) and households (Figure 5). Figure 4 shows that daily travel distance (G = 0.627) is distributed in a more inequitable manner among the population than daily travel time (G = 0.552). In Figure 5, the same curves were plotted using household as unit of analysis. The results are similar to that for individual travel and distance distributions, confirming that daily distance travel (G = 0.372) is a more inequitable quantity than daily travel time (G = 0.293).

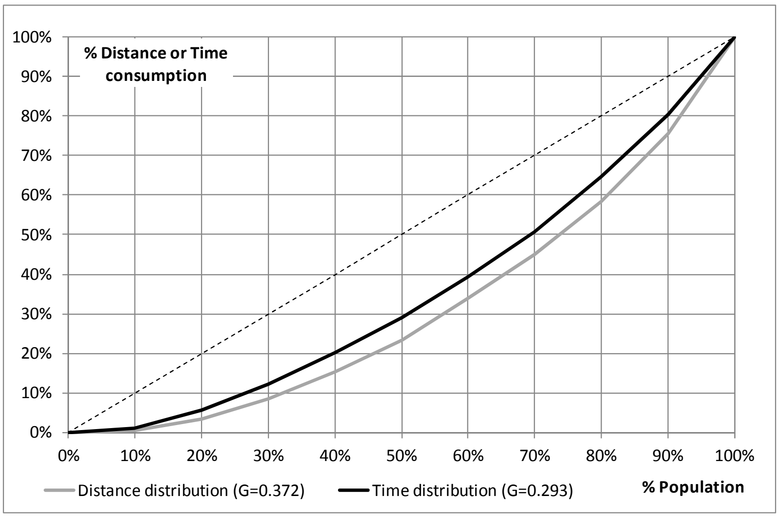

Figure 5 – Lorenz curves of household daily travel time and distance distributions. Expanded data.

Comparing Figures 4 and 5, it is possible to observe that the "immobility effect" in Lorenz curves is more important for individual distributions than for households. The fact that a family represents a unit of production appears more adequate to use a household as a unit of analysis to compute immobility or inequalities in transport consumption. Reasons why some individuals are "immobile" may be more related to lifestyle (Motte-Baumvol and Nassi, 2012) and not necessarily represent an inequality situation.

As a complement to the Lorenz curves, Table III shows values for Gini, Theil-T, and Atkinson measures.

Table III – Inequality measures for daily travel time and distance distribution. Expanded data.

Measure		Daily travel distance (DTD)		Daily travel time (DTT)	
		Households A	Individuals B	Households C	Individuals D
Gini		0.372	0.627	0.293	0.552
Theil-T		0.460	0.732	0.367	0.593
Atkinson	ε = 0.50	0.250	0.391	0.211	0.377
	ε = 1.00	0.545	0.732	0.580	0.898
	ε = 1.50	0.798	0.883	0.959	0.995
	ε = 2.00	0.909	0.928	0.994	0.998
	ε = 2.50	0.946	0.944	0.997	0.999

A comparison of household DTD and DTT distributions, as shown in columns A and C, respectively, indicate that travel time distribution (DTT) has lower values for Gini, Theil, and $A_{\varepsilon=0.50}$ index, but higher values for ε, and the results are quite different; travel distance distribution (DTD) shows lower values for the Atkinson index. The same situation is observed when comparing these indices for individuals (columns B and D). This is because travel distance distribution becomes more equal at the bottom and less equal at the top than the travel time distribution. Thus, as the degree of inequality-aversion increases, we attach more weight to the distribution at the lower end of the scale.

In his study, Atkinson (1970) showed that the Gini coefficient is a measure that *"...tends to give rankings which are similar to those reached with a relatively low degree of inequality aversion (ε) of the order of 1.0 or less..."*. Figure 5 shows variation in the Atkinson index for different values of the aversion to inequality parameter.

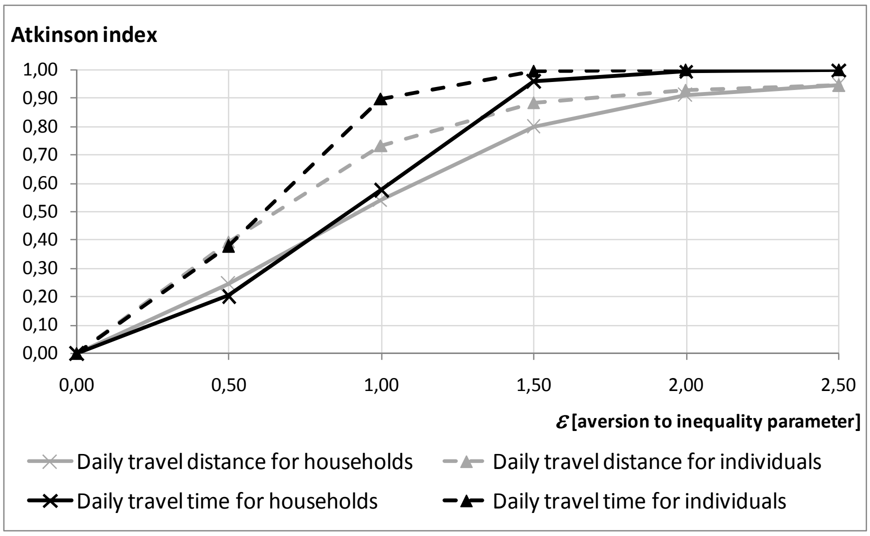

Figure 6 – Variations on Atkinson index value with different values of aversion to inequality parameter (ε)

DISCUSSION AND CONCLUSION

This study uses traditional economic measures of inequality to understand the degree of inequality in transport consumption. While inequalities in travel patterns have become increasingly quantified in Latin American cities, the analysis of distribution disparity in travel time and distance among the population has not been thoroughly examined.

The most important conclusion is that Daily Travel Time distribution (DTT) is more sensitive to the value of aversion to inequality parameter than Daily Travel Distance distribution (DTD) for both unit of analysis households and individuals. This indicates that conventional objective measures of inequality, such as the like Gini coefficient, show that the DTT distribution is more equal than the distance distribution (DTD). This situation changes with higher values of inequality aversion parameter (ε); in this case, DTD shows lower values for the Atkinson index.

The Atkinson index allows us to understand the normative judgment behind the inequality measure, so we strongly recommend that it is used in future research focused on urban transport inequality as a complement to traditional inequality measures.

Another significant result of this paper is that the levels of inequality in transport patterns observed in Córdoba are lower than values observed in larger cities such as São Paulo (Brazil), but with a similar proportion of persons that report no trips (immobility). Here, we must underline that household immobility appears to be a more adequate measure than personal immobility since differences between income groups of population are more evident when using household as a unit of analysis. Immobility values are related with the survey method, and comparisons between different countries or cities must consider this fact; for example, in Córdoba, the household travel survey only computed trips over 400 meters.

An important limitation of this research is that to apply the Atkinson index for the two variables of daily travel time (DTT) and distance (DTT), it is necessary to accept that a person who consumes a larger quantity of distance or time has a higher welfare level. This is an important simplification, but the authors consider that the principal contribution of this research is show a new method for quantifying inequalities in urban mobility. It is recommended for future studies to use a more comprehensive variable to represent the relationship between transportation and welfare, such as accessibility or generalized cost.

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