



Fair fares? How flat and variable fares affect transit equity in Los Angeles

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ABSTRACT

Transit agencies typically structure fares in one of five ways: 1) flat, 2) adjusted by distance traveled, 3) varied by time of day, 4) varied by mode, and/or 5) discounted based on rider characteristics. Despite the fact that each fare structure imposes different cost burdens on low-income versus higher-income riders, the relative equity of different fare structures has not been systematically evaluated. Using detailed travel-diary data from California, this paper investigates how varied transit use by low- and higher-income transit riders translates into divergent equity outcomes under six evaluated fare structures. Analysis reveals that low-income transit riders travel shorter distances, rely disproportionately on local rather than longer-distance modes, and make a higher share of transit trips during off-peak periods compared to higher-income riders. As a result, low-income riders pay far higher per-mile transit fares compared to more affluent riders in all but two of the tested fare scenarios. While flat fares are the least equitable, varying fares by distance, time-of-day, mode, or rider does not guarantee fare equity. Judged by riders' ability to pay, the benefits riders receive from a transit trip, and the cost of providing transit service, non-capped distance-based fares combined with time-of-day pricing result in the most equitable fare structure. Given robust technology to implement variable fares, transit agencies should reevaluate current fare structures and reform fare policies to ensure that all riders pay their fair share for transit.

1. Introduction

Transit agencies around the world have adopted a wide range of fare structures, which can be generalized into five categories: 1) flat, 2) adjusted by distance traveled, 3) varied by time of day, 4) varied by mode, and/or 5) discounted based on rider characteristics. Of these, flat transit fares are particularly common across the globe and dominant in the U.S. Despite their frequency, however, flat fares may not translate into equitable outcomes for riders. While equity remains an important goal to most transit operators (Nuworsoo et al., 2009), fare discussions are often swayed by budgetary concerns, increasing operational costs, and aversion to public backlash (Yoh et al., 2015; McCollom and Pratt, 2004). As a result, transit fare policies often present a paradox between espoused transit goals and current practices.

In order to realign transit agency aims with practices, this paper both presents a systematic evaluation of equity under different fare structures, and provides a much-needed update to fare equity policy research, much of which relies on decades-old and/or on-board survey data, and which may not reflect current transit use or be representative across wider populations. To fill these gaps, I investigated fare equity in the context of Los Angeles, the second largest American city and home to one of the nation's largest transit agencies, Los Angeles County Metropolitan Transportation Authority (LA Metro). Using travel-diary

survey data from the 2012 California Household Travel Survey (CHTS), I ask and answer two related research questions: 1) how does transit use vary by income? And 2) given divergent travel patterns, how equitable is LA Metro's current flat fare structure relative to alternative variable fare structures? Findings from this research present clear imperatives to realign espoused agency goals of equity with practiced fare structures.

2. Literature review

2.1. Defining equity

Equity's varied definitions yield inherent contradictions in policy solutions. For example, equity may be measured as a process—such as inclusion or exclusion in the planning process (for discussion see Willson (2001))—or as the distribution of transportation inputs relative to outputs or consumption (Taylor and Norton, 2009). Different units of analysis may likewise shape conclusions of equity, and researchers have previously considered equity across space, time, and groups. According to Taylor (2004), three often-competing types of equity in transportation may be pursued: 1) market equity, in which spending is proportional to the revenue or taxes paid by people, groups, or places; 2) opportunity equity, in which spending or resources are evenly distributed across people, groups, or places; or 3) outcome equity, in

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which spending produces equal levels of mobility or service across people, groups, or places.

While transit research tackles equity from many angles ranging from transit provision (Kaplan et al., 2014) to service distribution (Delbosch and Currie, 2011; Farber et al., 2014) to transit spending priorities (Taylor and Morris, 2015; Garrett and Taylor, 1999; Taylor et al., 2000), I focus the remainder of this discussion on how previous fare research has conceptualized equity. Most fare equity research assesses group (i.e., across income, racial/ethnic, or age groups) and market equity.

2.2. Measuring fare equity

Fare equity research is divided among studies assessing current fare structures (El-Geneidy et al., 2016), proposed changes to fare structures (Nuworsoo et al., 2009; Hickey et al., 2010), actual changes (Andrle et al., 1991; Nahmias-Biran et al., 2014), and hypothetical fare changes (Bureau and Glachant, 2011; Farber et al., 2014; Bocarejo and Oviedo, 2012; Bandegani and Akbarzadeh, 2016). Regardless of the scenario, most fare policy research examines only equity among transit riders rather than across the broader tax-paying public; this is in contrast to transit subsidy research, which evaluates equity across both riders and non-riders (see for example Hodge, 1995; Pucher, 1981).

Researchers typically measure fare equity in one of three ways. First, as percentage differences in out-of-pocket costs paid by rider groups under various fare structures (Nahmias-Biran et al., 2014; Nuworsoo et al., 2009; Farber et al., 2014; Bocarejo and Oviedo, 2012). Second, as the absolute dollar gains across income groups (Bureau and Glachant, 2011). And third, as the relative fare recovery (the fraction of operating costs for a particular trip are covered by a rider's fare) across rider groups (Cervero and Wachs, 1982; Mayworm et al., 1984; Bandegani and Akbarzadeh, 2016).

Cervero (1981) originally outlined three criteria to measure transit fare equity, which were later also employed by Nuworsoo et al. (2009): 1) the *benefits received criterion*, which holds that people should pay for transit in proportion to the benefit they receive from making a trip; 2) the *cost criterion*, which states that fares should vary to reflect the costs of transit service; and 3) the *ability to pay criterion*, under which transit fares should be charged in proportion to income or wealth, with lower-income riders paying less than higher-income riders.

These three criteria are difficult, if not impossible, to satisfy simultaneously; nevertheless, equity judgments can be drawn from assessing the three criteria in concert with one another. A fare structure is less equitable when low-income riders pay more per-mile compared to higher-income riders as such a fare structure violates both the benefits-received (i.e., all riders should pay the same per mile) and ability-to-pay (i.e., those with higher abilities to pay (incomes) should pay higher fares) criteria. A fare structure under which all riders pay the same per mile would be more, but not entirely, equitable under the three criteria; it meets the benefit-received criterion, but still violates the ability-to-pay criterion. Finally, a fare structure under which low-income riders pay less per mile would be deemed more equitable as it satisfies the ability-to-pay criterion. While it does not satisfy the benefit-received criterion, low-income riders paying less per mile squares with progressive tax structures, such as the income tax, which imposes lower cost burdens on the poor compared to the rich regardless of services received.

The cost criterion is difficult to assess as the cost of providing service varies across routes, direction of travel, and time of day. However, the higher costs of providing peak-hour services is well-established in transportation research (Taylor et al., 2000; Parody et al., 1990; Cervero et al., 1980), and thus fare structures that charge higher fares during peak than off-peak hours can be viewed as more equitable according to the cost criterion.

2.3. Equity in flat and variable fare policies

Flat fares, which charge the same fare no matter when, how far, or on what mode riders travel, have become increasingly popular over time. Many agencies believe flat fares are faster to collect, more transparent and easily understood by patrons, and cheaper to administer compared to variable fares (Yoh et al., 2015; Mayworm et al., 1984). Although pervasive, flat fares both create cross-subsidies between high and lower-income riders (Taylor et al., 2000), and are widely recognized as regressive (Cervero, 1981; Iseki and Taylor, 2010; Cervero et al., 1980; Luhrsens and Taylor, 1997; Cervero and Wachs, 1982). Flat transit fares typically fail to hold up to the above-discussed criteria because they fail to reflect variations across service costs, individual riders, or trips themselves. In addition, they depart from the transportation finance tenet that travelers should pay in rough proportion to their use of a system (Bandegani and Akbarzadeh, 2016).

Introducing variation into fare structures alters the equity calculus as judged across the cost, benefits-received, and ability-to-pay criteria. Transit agencies typically vary fare structures in one of three primary ways: 1) they introduce new fare categories, 2) they alter the basis, or unit, on which fares are calculated, or 3) they change the relative prices between different fare categories (McCollom and Pratt, 2004). This research focuses on the latter two variations, which address per-trip fares; I do not discuss new fare categories or transit passes, which raise additional and unique equity issues as discussed by Agrawal et al. (2011), Nuworsoo et al. (2009), and El-Geneidy et al. (2016). Transit agencies most commonly alter fare bases or change relative fare prices in one of four ways: they charge different fares by distance, by time of day, by mode, or by rider characteristics. Each approach yields different equity considerations, as discussed below.

2.3.1. Distance

Distance-based fares are typically operationalized in one of two ways: agencies either price fares based directly on distance traveled (Beijing, Seoul, Sydney, Washington, D.C.), or approximate distance through fare zones (Houston, London, Madrid, Johannesburg, Melbourne, Oslo, Paris, Philadelphia, Vancouver). In the U.S., the share of systems charging distance-based fares fell from 30 percent in 1994 to just 23 percent in 2015 (American Public Transportation Association (APTA) 2017a, 1994), although distance-based fares continue to be far more common on commuter rail systems (77%) than rail (17%), or bus (19%) (American Public Transportation Association (APTA), 2017b).

Researchers find that adopted or proposed distance-based fares typically create more equitable outcomes for riders (Bandegani and Akbarzadeh, 2016; Nahmias-Biran et al., 2014; Bureau and Glachant, 2011; Farber et al., 2014). For example, in 2009, Haifa, Israel shifted from flat fares to a zone plus time-of-day-based fare structure, which reduced fares for low-income riders (Nahmias-Biran et al., 2014). Similarly, Farber et al. (2014) found that shifting from flat to distance-based fares in Utah would reduce fares for riders earning under \$50,000, part-time workers, students, and seniors. In both cases, distance-based fares improve equity judged on the ability-to-pay criterion, although the equity effects vary based on the local geographical context (Bureau and Glachant, 2011; Farber et al., 2014). Because distance-based fares charge at a uniform per-mile rate, fares match the benefits received (i.e., higher fare for more benefits (distance traveled) received), which satisfies the benefit-received criterion. A distance-based structure performs moderately on the cost criterion by charging higher fares for longer distance services (which are more expensive to provide), but does not fully satisfy the criterion as distance-based fares do not account for temporal variations in transit service costs.

2.3.2. Time of day

Agencies that vary fares by time of day usually charge higher fares during peak periods and lower fares during off-peak periods. Peak fares typically aim to either recoup the higher costs of providing peak hour

service (Cervero, 1990), shift passengers from peak to underutilized midday and evening periods (McCullom and Pratt, 2004), or increase ridership and revenue rather than explicitly improving equity (Donnelly et al., 1980).

While charging higher fares during peak periods is practiced by transit systems across the world (Haifa, London, Sydney, Santiago), varying fares by time of day is less common than charging based on distances or zones; in the U.S., just 10 percent of agencies report varying prices by time of day (Yoh et al., 2015) and 7.6 percent report peak-hour surcharges (American Public Transportation Association (APTA), 2017a). Like distance-based fares, a higher share of commuter rail systems charge peak period surcharges (12%) compared to bus (6%) or rail (9%) (American Public Transportation Association (APTA), 2017b). While time-of-day pricing is relatively rare in the U.S., it has proven equity successes when implemented. For example, Nahmias-Biran et al. (2014) find that Haifa, Israel's shift from a flat fare to zone and time-of-day structure reduced fares paid by low-income travelers. And in the U.S., Hickey et al. (2010) find that a proposal to discount off-peak fares in New York City would have shifted fare burdens from riders boarding in low-income and minority neighborhoods to more affluent and white-dominant neighborhoods. These cases demonstrate that time-differentiated fares may also improve equity as judged by the ability-to-pay criterion.

Parody et al. (1990) find that in the U.S., one peak-hour trip costs 45 percent more than one off-peak trip. Peak-pricing helps to better align service costs with fares and thus satisfies the cost criterion. Finally, time-of-day fares often satisfy the benefit-received criterion (where benefits are measured as miles traveled) as commute trips, taken disproportionately during peak periods, are typically longer distances compared to off-peak trips.

2.3.3. Mode

Some agencies charge different fares or operate entirely different fare structures across modes; agencies most commonly charge higher fares for express or longer-distance services and lower fares for shorter-distance services such as local buses. For example, transit agencies in both London and Washington, D.C. apply a lower flat-fare structure to bus service, but a higher distance-based fare structure to rail service (Washington Metropolitan Area Transit Authority, 2017; Transport for London, 2017). Charging higher fares for modes that are more expensive to operate can satisfy the cost criterion and improve—but not fully satisfy—the other two criteria. Mode-based fares can improve ability-to-pay equity outcomes because higher-income riders travel disproportionately on express bus and rail services (Luhrsen and Taylor, 1997). However, the ability-to-pay criterion is unlikely to be fully satisfied as low-income riders typically travel shorter distances than higher-income riders regardless of mode (Luhrsen and Taylor, 1997). In addition, marginally higher fares for longer-distance modes may not fully offset the additional distance traveled; therefore, the benefits-received criterion may be improved, but not fully satisfied under mode-based fares alone.

2.3.4. Group

Transit agencies frequently combine flat fares with discounts for select groups of riders, such as seniors, disabled riders, or students. Discounts for seniors are common around the world (see for example evaluations of senior fare discounts in Seoul (Myung-Jin et al., 2018) and Scotland (Rye and Mykura, 2009)) and nearly ubiquitous in the U.S., where agencies that receive federal funds are required to discount senior fares during off-peak periods (McCullom and Pratt, 2004). Seniors take longer trips on average (7.7 vs. 6.3 miles), but have similar household incomes compared to other adults (California Department of Transportation, 2012). Discounted senior fares, therefore, mean that seniors pay a fraction of the cost paid by other travelers despite receiving similar benefits, incurring similar costs, and having roughly equal incomes. As a result, senior fare discounts typically violate all

three equity criteria. Transit agencies also commonly offer youth pass programs, although Nuworsoo et al. (2009) find that retaining youth passes in fare restructuring does little to ameliorate inequities.

Rider-based discounts rarely account for broader income equity. Of the 25 largest transit agencies in the United States, only four reduce fares for low-income households. In some cases—such as LA Metro, which provides Rider Relief coupons to reduce the cost of trips by 10 percent—the discount may not be enough to offset the inequity of flat fares. Instead, steeper discounts are required to overcome fare inequity based on the ability-to-pay. For example, San Francisco Municipal Transportation Authority discounts fares by 50% for qualifying low-income riders (San Francisco Municipal Transportation Agency, 2017). Of course, while discounting low-income riders improves equity based on the ability to pay criterion, it actually may be inequitable to higher-income riders based on the benefits-received and cost criteria.

3. Data and methodology

3.1. Data in fare equity research

Previous research on transit fare equity has utilized on-board surveys (Iseki and Taylor, 2010; Nuworsoo et al., 2009; Luhrsen and Taylor, 1997; Nahmias-Biran et al., 2014) and fare card swipe data (Hickey et al., 2010). This research, by contrast, utilized data from the 2012 California Household Travel Survey (CHTS), which provides detailed records of individuals' travel and activities for a single survey day.

Although household travel surveys have been used to analyze distance-based fare equity (Farber et al., 2014), such rich data have never before been used to evaluate the relative equity of different fare structures. Statewide household travel survey data offer two advantages over on-board surveys and fare card swipe data previously used to evaluate fare equity. First, household travel surveys are representative of the wider population, and thus provide a more representative sample of transit use. On-board surveys, on the other hand, intercept transit riders on select routes, thus excluding some riders entirely and making survey quality highly dependent on the methods used to sample routes, vehicles, and people (Richardson et al., 1995). In addition, on-board surveys have high nonresponse rates; LA Metro reports a 50 percent response rate for yearly on-board surveys (Los Angeles County Metropolitan Transportation Authority, 2017a). Together, high rates of nonresponse plus the omission of riders, vehicles, or routes, may produce a non-representative sample of transit riders. Like on-board surveys, smart card data may not be representative of the wider transit-riding population as smart card market penetration may be insufficient or skewed towards certain types of riders (Utsunomiya et al., 2006).

Second, household travel surveys offer advantages over on-board surveys and fare card swipe data as they collect detailed travel data in conjunction with socioeconomic and household information. Associated socioeconomic data allow for analysis by and across different traveler groups. Fare card swipe data, by contrast, while rich in location, time, and fare information, are divorced from the socioeconomic characteristics of fare card holders, and thus must be supplemented with additional datasets (Pelletier et al., 2011). Even with supplemental data, researchers are often limited to analyzing travel originating and ending in certain types of neighborhoods (see Hickey et al., 2010), and cannot draw conclusions about travelers themselves. Travel surveys also offer advantages over on-board surveys as they capture a complete day or week's worth of transit travel behavior, compared to the single trip typically captured by the on-board intercept survey.

3.2. California household travel survey

The household travel survey employed in this research, the CHTS, used stratified probability sampling to randomly select households from

within 30 geographical strata across California. To allow for inferences about the sampled population, the CHTS developed weights to reflect the likelihood of household selection and to align the sample distribution with population distributions. Weighted results presented in this paper therefore account for “the biases associated with sampling and robustness of the data collected” (California Department of Transportation, 2013, 86).

To evaluate how varied fare structures would affect transit riders within a similar built environment and transit agency context, I restricted my sample to only travelers who made a trip on LA Metro, which provided more unlinked passenger trips than any other U.S. transit agency in 2014 (American Public Transportation Association (APTA), 2017b). I included only adults ages 20 and older who reported income, which is integral to an equity analysis.¹ While income non-response in the CHTS was relatively high (9.8%), this is a common trend across household surveys (Moore and Welniak, 2000). CHTS respondents who did not report income were significantly older (54 vs. 51), but did not significantly vary across other socioeconomic characteristics, and were equally likely to take transit on the survey day compared to those who reported income. Therefore, excluding income nonresponsive households is unlikely to introduce systematic bias into an analysis of transit riders. The final sample includes 537 adults who rode LA Metro on the survey day.

3.3. Evaluating six fare scenarios

I first compared the socioeconomic characteristics and travel patterns of LA Metro riders living above and below the living wage. I defined the living wage using the Massachusetts Institute of Technology Living Wage Calculator for Los Angeles County in 2015 (Glasmeyer, 2016); the calculator accounts for regional costs, spending, and adjusts the earnings threshold based on household size and composition. I refer to travelers living below the living wage as “low-income” adults and those earning above the living wage as “higher-income” adults. Socioeconomic and travel differences between income groups underpin the equity outcomes of different fare structures. I tested if demographic and travel differences between the groups were significant and used the Bonferroni Correction to adjust p-values and correct for multiple comparisons that could inflate the odds of making a Type 1 error.

Using LA Metro riders, I then evaluated how six different fare structures affect the per-mile fare paid by higher-income and low-income riders. The six scenarios include the flat-fare structure currently in place at LA Metro and five additional hypothetical fare scenarios that vary fares by distance, time of day, mode, and/or rider group (i.e., senior discount). The hypothetical fare scenarios are based closely on either structures previously considered by LA Metro or adopted by other transit agencies around world (Hyman, 2014). I present the six fare scenarios in Table 1 and discuss the assumptions made in each scenario in turn below. For each scenario, I weigh equity considerations using the three criteria discussed earlier: benefits received, cost, and ability-to-pay. With the exception of the sixth fare scenario (which combines distance-based fares with an off-peak discount), each examined fare structure introduces only a single variation compared to flat fares. This is intentional in order to isolate the effects of each fare structure on equity. Of course, more possible combinations of these fare scenarios exist than can be explored in a single paper. Agencies considering fare restructuring must consider how each structure, as well as local context, may affect equity outcomes.

3.3.1. Flat fares

Flat fares are currently employed by LA Metro, a majority of all U.S. transit agencies, and many agencies around the world (American Public

Transportation Association (APTA), 2017a). For the flat fare policy scenario, I priced each trip at \$1.75 regardless of mode, time of day, distance, or person making the trip. \$1.75 is the fare charged by LA Metro as of 2018 (Los Angeles County Metropolitan Transportation Authority, 2016).

3.3.2. Distance

The average CHTS respondent who traveled on LA Metro on the survey day paid \$0.32 per mile. I used this average per-mile cost, regardless of mode or time of day, as the fare basis for the distance-based fare scenario. Within the distance-based scenario, I present a scenario with no minimum or maximum fare (2a), as well as a scenario with imposed minimum and maximum fares (2b). Employing minimum and maximum fares is common practice among transit agencies. I set the minimum fare at the current flat fare price of \$1.75, and cap fares at \$6.00, which is the maximum fare imposed by the Washington Metropolitan Area Transit Authority (WMATA), the only major U.S. transit agency that sets true distance-based rather than simplified zone-based fares.

3.3.3. Time of day

Agencies that vary fares by time of day may market fares as off-peak discounts or as peak-hour surcharges. Despite this distinction, the two are equivalent when measuring relative differences between fares paid. In the time-of-day fare scenario, I discounted peak-hour trip fares by \$0.50; therefore, off-peak fares are \$1.25 compared to \$1.75 peak fares. I defined peak hour trips as those that departed weekdays between 6:00 am and 9:00 am or between 4:00 pm and 7:00 pm.

3.3.4. Mode

LA Metro currently differentiates fares for express bus trips, which cost \$2.50 instead of the normal \$1.75 fare (Los Angeles County Metropolitan Transportation Authority, 2016). In this scenario, I not only applied this \$2.50 fare to express bus services, but also extended the \$2.50 fare to all rail trips, which are closer in average distance traveled to express bus trips than they are to local buses. As a result, in this fare scenario, local bus trips cost \$1.75, while all express bus and rail trips cost \$2.50.

3.3.5. Group

LA Metro currently discounts fares for two groups of riders: seniors and K-12 students. Because I included only adults ages 20 or older in this study, no K-12 students are included. Therefore, the group fare scenario included only the senior fare discount. LA Metro discounts senior fares to \$0.75 during peak hours and \$0.35 during off-peak hours (Los Angeles County Metropolitan Transportation Authority, 2016). I used this existing fare structure to evaluate group-based fare equity.

3.3.6. Combining fare policies

The above variable fare structures are not always implemented in isolation from others; for example, as previously discussed, LA Metro imposes flat fares, but also senior discounts that vary by time of day. Other agencies likewise impose additional layers of variation. For example, WMATA charges higher base *and* per-mile fares during peak hours on its Metrorail than it does during off-peak periods, while the Metrobus system operates a flat fare at all times of the day, with surcharges only for express services. While dozens of fare structure combinations exist, the sixth fare structure evaluated in this research combines the two variable fare structures that would affect all transit riders: distance-based and time-of-day pricing.

In none of these scenarios did I consider the potential effects for cost recovery. While cost recovery is an important component of many fare restructuring discussions (Yoh et al., 2015; McCollom and Pratt, 2004), the intent of this paper is to focus on the rider-side equity effects rather than broader fiscal implications. Other researchers find that revenue impacts largely depend on the proposed structure under discussion

¹ CHTS respondents indicate age categorically. Age 20 is the lower bound of the age category that includes only adults ages 18 and older.

Table 1
Six Fare Scenarios.

Fare Structure	Fare Basis	Measure
(1) Flat Fare	Trip	Each transit trip costs \$1.75
(2a) Distance-based fare, no minimum/maximum fare	Mile/kilometer	Each mile traveled costs \$0.32
(2b) Distance-based fare, with minimum/maximum fare	Mile/kilometer	Each mile traveled costs \$0.32 Minimum fare: \$1.75 Maximum fare: \$6.00
(3) Off-peak discount	Time of day	\$1.75 during peak hours; \$1.25 during off-peak hours (\$0.50 discount)
(4) Mode-based	Mode	Local bus: \$1.75 Express bus: \$2.50 Rail: \$2.50
(5) Group-based	Rider	Adults: \$1.75 Seniors: \$0.75 during peak hours, \$0.35 during off-peak hours
(6) Distance-based with off-peak discount, (2a) + (3)	Mile/kilometer and time of day	Each mile traveled costs \$0.32 All trips taken during off-peak periods are discounted by \$0.50

(Nuworsoo et al., 2009) or amount of fare increase (Wang et al., 2015). Notably, some researchers have argued that differentiated fares typically increase revenues and the “industry’s financial posture” (Cervero, 1981, 211; Chien and Tsai, 2007).

4. Findings

4.1. Transit use by low- and higher-income ride

Table 2 shows socioeconomic statistics for all transit riders earning above and below the living wage. Critically, more than three-quarters (77%) of respondents who rode transit on the survey day earned below the living wage, highlighting the importance of creating equitable fare policy that does not unduly burden the majority of riders.

Low-income transit riders in Southern California are generally less white, have lower educational attainment, lower rates of citizenship, and are disproportionately carless, findings that are consistent with the transportation literature (Pucher and Renne, 2003; Blumenberg, 2013). Low-income households have far lower access to personal cars than

Table 2
Socioeconomic Statistics, Survey-Day Transit Riders in Southern California.

	Under Living Wage	Above Living Wage	Sig. ¹
<i>Individual Characteristics</i>			
% Holding a Transit Pass	53.2%	68.1%	***
Mean Number of Transit Trips/Week	8.0	7.1	NS
<i>Race/Ethnicity</i>			
% Non-Hispanic Asian	3.2%	10.6%	***
% Non-Hispanic Black	10.7%	12.1%	NS
% Non-Hispanic White	16.2%	52.5%	***
% Hispanic	67.1%	24.1%	***
% Seniors (age 60+)	25.9%	29.4%	NS
% Female	58.0%	50.1%	NS
% Student	13.4%	13.3%	NS
% Citizen	41.3%	75.6%	***
% Bachelor’s Degree or Higher	10.2%	55.1%	***
<i>Household Characteristics</i>			
% Zero-Vehicle Households	48.1%	17.6%	***
Mean Number of Household Vehicles ²	1.47	1.91	***
Cars per Licensed Driver	0.67	0.87	***
Mean Household Income	\$19,422	\$99,422	***
Sample Size (individuals)	726	339	
Percent of Sample	77%	23%	

¹ P-values were adjusted using Bonferroni Correction in order to correct for multiple comparisons. Actual p-values vary based on number of tests conducted. Confidence levels: *90%, **95%, ***99%, NS Not Significant.

² Among households with at least one household vehicle.

high-income households and nearly half of low-income households are carless (48%) compared to less than one-fifth (18%) of higher-income households. Even among households that do own a car, low-income households own fewer cars per household (1.49 vs. 1.91) compared to higher-income households.

Table 3 shows the temporal, modal, and trip-level travel statistics for LA Metro riders earning above and below the living wage. Low- and higher-income riders take approximately the same number of transit trips per week and about one in three riders from each group holds either a seven or 30-day transit pass; overall levels of transit pass use, however, belie the types of passes held by travelers by income. About 28 percent of travelers earning above the living wage hold a 30-day pass compared to just 19 percent of those earning below the living wage. Conversely, nearly 12 percent of lower-wage riders use a seven-

Table 3
Average Number of Daily Trips and Distances by Mode and Income, LA Metro Riders.

	Under Living Wage	Above Living Wage	Sig. ¹
<i>Trips</i>			
Share of Trips during Peak Hours	41.9%	54.4%	**
Mean Transit Trip Distance (miles)	5.05	6.84	***
Off-peak	5.22	6.09	NS
Peak	5.19	7.33	***
<i>Mode</i>			
Local Bus	74.0%	46.8%	***
Mean Distance	4.40	4.67	NS
Express Bus	4.3%	4.7%	NS
Mean Distance	8.87	8.74	NS
Rail	21.0%	46.8%	***
Mean Distance	6.90	8.10	NS
<i>Population</i>			
Share with transit pass ²	30.8%	29.8%	***
Number of weekly transit trips ²	8.45	8.37	NS
% of Income Group Trips made by Seniors	23.2%	31.7%	NS
% of Senior Trips, Peak	32.7%	39.5%	NS
Mean Distance	7.40	8.10	NS
% of Senior Trips, Off-peak	67.3%	60.5%	NS
Mean Distance	5.40	5.91	NS
<i>Trips/Individuals</i>	1603/536		

Peak periods defined as trips that departed between Monday and Friday, 6:00am to 9:00am, 4:00 pm to 7:00 pm. All trip distances reported in miles. Seniors defined as ages 60+. Excludes commuter rail trips (n = 27) and trips with recorded distances of 0 miles (n = 21).

¹ P-values were adjusted using Bonferroni Correction in order to correct for multiple comparisons. Actual p-values vary based on number of tests conducted. Confidence levels: *90%, **95%, ***99%, NS Not Significant.

² Measured as share of income group.

day pass compared to less than 2 percent of higher-wage travelers. These statistics are troubling as monthly passes often translate into deeply discounted trips compared to either per trip fares or even weekly passes; and yet, the high up-front costs of these money-saving passes are frequently out of financial reach for those who could benefit from them the most (Agrawal et al., 2011; El-Geneidy et al., 2016).

In addition to lower transit pass ownership, low-income LA Metro riders make a significantly lower share of trips during peak hours (41.9%) and significantly shorter trips (5.05 miles) compared to higher-income riders (54% of trips during peak hours, 6.84 miles, respectively). Differences in distances traveled by income are particularly prominent during peak periods.

One explanation for why low-income transit riders travel shorter distances is the mode share by income group. Previous research finds that while low-income riders disproportionately rely on local transit and bus services, higher-income transit riders more heavily utilize suburban commuter services and express buses, which carry riders longer distances (Iseki and Taylor, 2010; Garrett and Taylor, 1999; Luhsen and Taylor, 1997). Table 3 reflects these previous findings: while lower- and higher-income riders travel similar distances on each of the three modes, the modal split between the two groups is significantly different. Three-quarters (74%) of trips made by low-income riders were made on local bus, compared to fewer than half (47%) of trips made by higher-income riders; higher-income travelers made nearly all other trips on rail (47%) while lower-income travelers made just one in five (21%) trips by rail. As a result, mode split, rather than how different income groups use a particular mode, largely explains shorter average trip distances by low-income LA Metro riders.

In addition to how far people travel, when they travel is important to distinguish when assessing equity using the cost criterion. Fig. 1 shows the temporal distribution of weekday transit trips by low- and higher-income LA Metro riders. Although both groups exhibit peaked

travel behavior, over half (54%) of trips made by higher-income travelers were made during peak hours compared to just 42 percent of low-income trips. The observed temporal patterns square with known employment trends among low-income travelers including more varied work schedules (i.e., less likely to work a 9:00 am – 5:00 pm job), and more frequent non-work transit trips compared to higher-income people (Giuliano et al., 2001).

The different transit use patterns by low- and higher-income transit riders have direct implications for fare equity under different fare structures; results of the six fare scenario analysis are presented below.

4.2. How fair are different fare structures?

Fig. 2 highlights the results of six fare policy scenarios and depicts both the cost per-mile paid by low- and higher-income riders, and the percentage (more or less) that lower-income riders pay per mile relative to higher-income riders. Using the three equity criteria—benefit received, cost, and ability to pay—all fare structures prove more equitable compared to a flat fare structure. I discuss the results for each below.

While flat fares (Scenario 1) do not produce the highest per-mile fares, they do produce the least equitable as judged on a cost-per-mile basis. Under a flat fare structure (the current LA Metro fare structure), low-income transit riders pay 29 percent more per mile than higher-income transit riders do.

Distance-based fares have divergent equity outcomes depending on if minimum and maximum fares are imposed. When no minimum or maximum fare is imposed (Scenario 2a), per-mile fares are equalized, which improves equity when evaluated under the benefit-received criterion. Distance-based fares perform moderately on the cost criterion by charging higher fares for longer distance services (which are more expensive to provide), but fail to account for the temporal variations of



Shaded areas indicate peak periods: 6:00-9:00am and 4:00-7:00pm.

Fig. 1. Temporal Distribution of Weekday LA Metro Transit Trips by Income Group.

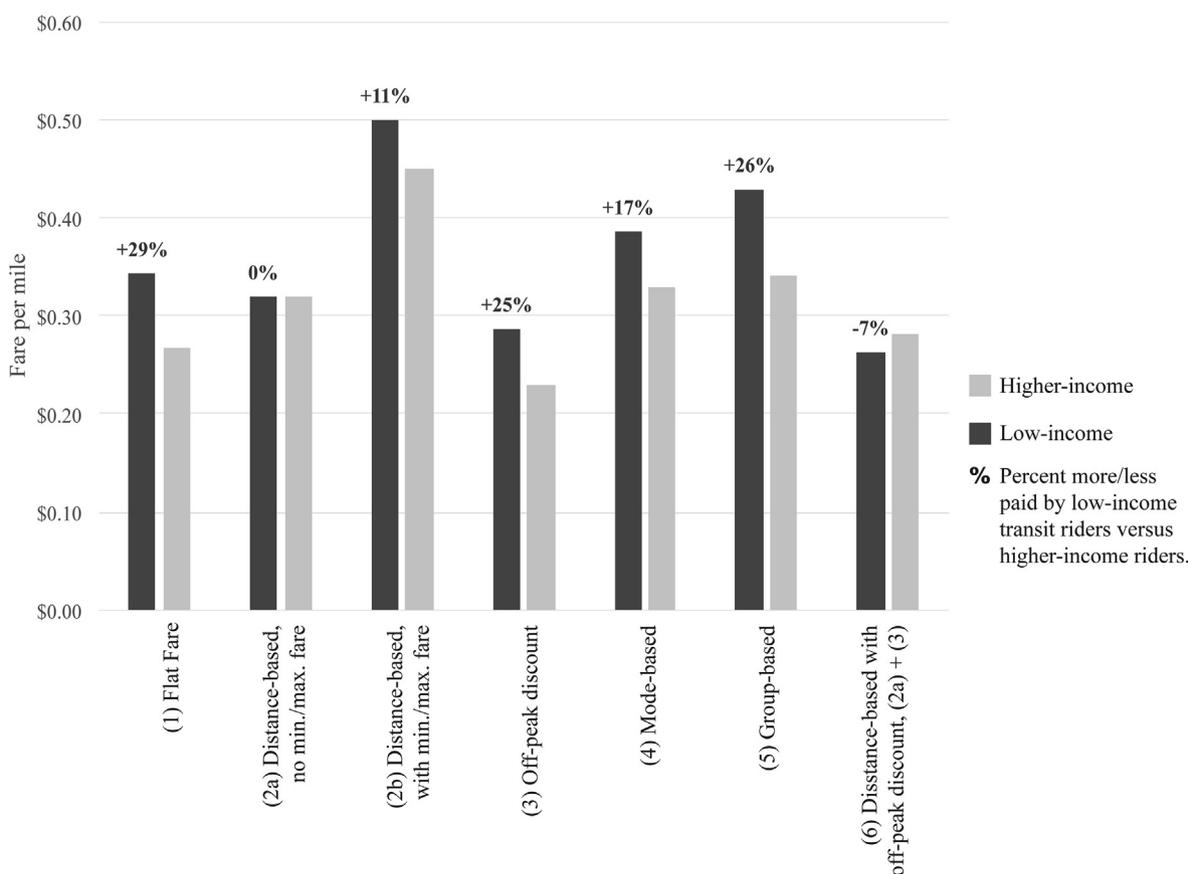


Fig. 2. Six Fare Scenarios.

operating transit. Per-mile, distance-based fares improve upon the ability-to-pay criterion by reducing the imbalances present under flat fares; however, distance-based fares do not fully satisfy the ability-to-pay criterion as all riders pay equal rates per mile regardless of income.

If minimum and maximum fares are imposed, however, distance-based fares are far from equitable (Scenario 2b). While this fare structure substantially reduces, it does not erase the per-mile cost disparities between low- and higher-income riders, largely because it imposes minimum fares on riders who travel short distances (disproportionately low-income), while capping fares for those traveling longer distances (disproportionately higher-income). Elimination of base fares, or further discounting of off-peak fares would improve equity as judged by the benefits-received and ability-to-pay criteria.

Like distance-based fares, introducing off-peak fare discounts (Scenario 3) shrinks the gap between the average per-mile costs paid by higher- and lower-income riders because low-income riders make a smaller share of trips (43%) during peak periods compared to higher-income riders (54%). Despite the shrinking gap, however, low-income riders still pay 25 percent more per-mile compared to higher-income riders. Thus, a simple off-peak discount performs poorly across both the benefit-received criterion (as costs do not equal benefits received (i.e., miles traveled) across different income groups), and on the ability to pay criterion, as per-mile fares are not charged in proportion to income. The off-peak discount's limited effect on rectifying flat fare inequities highlights that most of the fare imbalances stem from different trip lengths and less so from different trip times. Nevertheless, a simple off-peak discount proves superior to a flat fare structure on the final criteria: off-peak discounts reflect the higher costs of providing a peak-hour trip and thus satisfy the cost criterion.

Under a mode-based fare structure, modes on which people travel longer distances are subject to higher fares; however, such a fare structure is a rough approximation of distance at best. Average per-mile

fares remain 17 percent higher for low-income riders compared to higher-income riders, who both travel disproportionately on longer-distance modes, and also travel farther on all modes compared to low-income travelers. For example, the average rail trip taken by higher-income travelers is 17 percent longer than the average rail trip taken by low-income transit riders, although these differences are not statistically significant. Thus, while the mode-based fare structure makes improvements across all three equity criteria compared to flat fares, it does not eliminate fare inequities.

Group-based fares do the least to ameliorate inequities between low- and higher-income transit riders. Under a group-based fare structure, low-income riders still pay 26 percent higher fares compared to higher-income riders. With no statistical differences between either the share of seniors in each income group or how far seniors travel in each group travel, seniors effectively maintain the equity outcome of flat fares. Therefore, like flat fares, discounted senior fares violate both the ability-to-pay and benefits-received criteria. However, variable pricing among seniors—with peak trips costing \$0.75 and off-peak trips costing \$0.35 under current LA Metro fare policy—does satisfy the cost criterion for at least a subset of riders.

The only scenario in which all three equity criteria are fully satisfied is the final scenario, Scenario 6, which combined Scenarios 2a and 3 to incorporate both a distance-based fare (\$0.32 per mile) and an off-peak discount (-\$0.50). Like in Scenario 2a, no fare maximum or minimum is imposed. Off-peak discounting accounts for lower service provision costs during off-peak hours and satisfies the cost criterion. Low-income riders pay, on average, 7 percent lower per-mile fares compared to higher-income riders—primarily due to shorter trip distances—thus satisfying the ability-to-pay criterion. And because fares are charged at a uniform per-mile rate, fares match the benefits received (i.e., higher fare for more benefits (distance traveled) received), satisfying the benefit-received criterion.

5. Discussion

Low-income transit riders in Los Angeles travel significantly shorter distances, travel more on local buses, and make a lower share of trips during peak-hours. Consequently, they pay far higher per-mile transit fares compared to higher-income riders despite consuming service that is frequently less costly to provide. The six fare structure scenarios tested here reveal that *any* type of fare variation improves equity outcomes compared to flat fares when measured across three equity criteria: benefits received, ability to pay, and cost. Specifically, a fare structure that both charges a per-mile fare and discounts off-peak fares yields the most equitable results by better reflecting the marginal costs of providing service, charging the same per-mile rate per rider, and yielding lower total transit fares for low-income riders who typically travel shorter distances.

The slightly lower per-mile fare paid by low-income riders in Scenario 6 (off-peak discount plus distance based) raises a final question: how low must fares be to be truly equitable across incomes? For example, under Scenario 6, low-income riders pay 7 percent lower total fares on average compared to higher-income riders. However, the average income of a person earning below the living wage is 80 percent lower than a person earning above the living wage. Therefore, even though low-income riders pay lower fares than higher-income riders, the relative cost of their fares does not truly reflect their relative ability to pay. To more closely mirror ability to pay, transit agencies should consider a final amendment to variable fare structures: discounting per-mile fares for lower-income riders. For example, a household earning 50 percent of area-wide median income could receive a 50 percent reduction on per-mile fares; while not a perfect reflection of ability to pay, an income-based discount would further promote equity as measured by ability to pay. Some agencies already *do* reduce fares for low-income riders;² however, deductions on flat fares may not be enough to overcome inequity due to the different distances traveled by income. For example, LA Metro provides Rider Relief coupons to reduce rider costs by 10 percent (Los Angeles County Metropolitan Transportation Authority, 2017b), which is not enough to offset the fare inequity stemming from different distances traveled by income group. To overcome per-mile inequities, low-income discounts must be much steeper to achieve ability-to-pay equity. For example, San Francisco Municipal Transportation Agency discounts fares by 50 percent for qualifying low-income riders (San Francisco Municipal Transportation Agency, 2017). While income-based discounts applied to flat fares certainly would improve equity measured by the ability-to-pay criterion, they still may not reflect equity measured by the mile, nor do they reflect temporal cost variation. Instead, a distance-based and off-peak discounted fare structure remains the strongest performer across the three equity criteria.

Unexplored in depth by this research, but critical to any discussion of fare reform, are transit passes. As currently structured, monthly passes can provide marginal trip costs lower than individual fares. But like flat fares, passes typically fail to meet the ability-to-pay, cost, and benefits-received criteria. In addition, passes' higher up-front costs make them financially out of reach for many lower-income travelers who could most benefit from lower per-trip fares (El-Geneidy et al., 2016; Agrawal et al., 2011). While replacing a flat with a distance and time-based fare can greatly improve equity, comprehensive reform should also consider the role of passes in shaping equitable access to transit.

² Of the 25 largest U.S. transit agencies, only five agencies currently discount fares based on income. The five agencies include: LA Metro, San Francisco Municipal Transportation Agency, King County Metro (Seattle, WA), Miami-Dade Transit, Tri-Met (Portland, OR). A sixth agency, Metro Transit in Minneapolis/St. Paul began a low-income fare pilot in April 2017 (Metro Transit, 2017).

Barriers to fare restructuring—such as institutional inertia or fear of ridership loss—persist, but the time may now be ripe to adopt more variable pricing on transit. Smartcard technology makes variable fares far easier to implement than in the past, and new modes and finance innovations have accustomed travelers to variable pricing in transportation. Many travelers routinely pay fares that vary by length of time, time of day, or distance for shared mobility services such as carshare, bikeshare, and ridehailing. For example, Uber and Lyft calculate fares by summing a booking fee, per-mile cost times miles driven, and per-minute cost times minutes traveled. Drivers, too, are now being offered pay-as-you-drive insurance with per-mile rates, tolls may vary by distance traveled and time of day, and states around the country are piloting road use charges that price each mile driven (see California Department of Transportation, 2016). Varying transit fares by distance or time may prove a natural extension of this trend. Future fare considerations will certainly weigh competing objectives; however, where “effectiveness and efficiency [have been] the driving forces” behind much transportation decision making (Hodge, 1995, 374), equity, too, must be a primary objective in setting transit fares.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.cstp.2018.09.011>.

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