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Do Compact, Accessible, and Walkable Communities Promote Gender Equality?



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# Do Compact, Accessible, and Walkable Communities Promote Gender Equality?

A Research Report from the University of California Institute of Transportation Studies

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**16. Abstract**

Directing growth towards denser communities with mixed-use, accessible, and walkable neighborhood design has become an important strategy for promoting sustainability, but few studies have examined whether compact development strategies could help reduce within-household gender disparities in spatial behavior by increasing accessibility. We analyze spatial behavior of heterosexual married couples in Southern California based on the 2012 California Household Travel Survey and find that households living in areas with greater regional accessibility and neighborhood walkability have smaller, more centered, and more compact activity spaces overall compared to households in less compact areas, and that married pairs living in more accessible areas have greater equality in the size and centeredness of their activity spaces. Results support our hypothesis that compact development provides married couples greater flexibility in how they divide household out-of-home activities by making destinations more convenient. Future research and planning efforts should carefully consider which aspects of compact, accessible development are most effective for a given local context.

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# Do Compact, Accessible, and Walkable Communities Promote Gender Equality?

UNIVERSITY OF CALIFORNIA INSTITUTE OF TRANSPORTATION STUDIES

March 2018

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# Executive Summary

Directing growth towards denser communities with mixed-use, accessible, and walkable neighborhood design has become an important strategy for promoting sustainability because compact communities could encourage shorter driving trips and greater transit usage, walking, and cycling by clustering potential daily activity destinations near residential and work locations. Could compact development also help lessen gender disparities in spatial behavior by making destinations more convenient, reducing travel time, and lowering the overall spatial and temporal fixity of activities?

We analyze spatial behavior of heterosexual married couples in Southern California based on the 2012 California Household Travel Survey and find that households living in areas with greater regional accessibility and neighborhood walkability have smaller, more centered, and more compact activity spaces overall compared to households in less compact areas, and that married pairs living in more accessible areas have greater equality in the size and centeredness of their activity spaces. We account for residential selection bias in our multivariate analysis and find that a ten unit increase in near-residence Walk Score was associated with a 12-18% decrease in activity space size, a 6-8% decrease in residential distancing, and a 12-13% increase in spatial concentration for both men and women. Men and women, however, had significantly different activity space behaviors regardless of their neighborhood type. Compared to women, men on average had larger activity spaces and conducted their activities farther from home.

Overall, results support our hypothesis that compact development provides married couples greater flexibility in how they divide household out-of-home activities by making destinations more convenient and lowering the overall spatial fixity of these activities. Policy makers should proceed cautiously, however, with the recognition that not all compact, accessible areas are created equally because the design and influence of compact development can vary greatly across socio-demographics and by neighborhood. Future research and planning efforts should carefully consider which aspects of compact, accessible development are most effective for a given local context.

# Introduction

Sustainable development plans increasingly call for more compact, accessible, and walkable neighborhood design in order to reduce vehicle travel and associated greenhouse gas emissions. In California, Senate Bill 375 mandates regional planning organizations align their transportation plans with sustainable land use and development strategies to achieve this goal. In response, the Southern California Association of Governments' (SCAG's) recent plan directs nearly 50% of housing and employment growth between 2010 and 2040 into walkable and compact neighborhoods within a one-half mile walking distance from a well-serviced transit stop, or High Quality Transit Areas (HQTAs) (Southern California Association of Governments, 2016). These neighborhoods could encourage shorter driving trips and greater transit usage, walking, and cycling by clustering potential daily activity destinations near residential and work locations (Houston et al., 2015; Spears et al., 2016).

Could compact development also help lessen gender disparities in spatial behavior by making destinations more convenient, reducing travel time, and lowering the overall spatial and temporal fixity of activities? Available evidence suggests gender disparities in travel and activity patterns are influenced by urban form and development patterns. For instance, suburban sprawl can exacerbate gender disparities in daily household responsibilities and travel because segregated and dispersed land uses separate private and public realms and can constrain women to their immediate neighborhoods (Handy, 2006; Hayden, 2002). In contrast, New Urbanist neighborhood design could help counter the social isolation of women in suburbia by integrating pedestrian accessible mixes-use centers (Fagan and Trudeau, 2014), and compact communities with denser land use and better transit service could help reduce the disproportionate chauffeuring responsibilities of women (Boarnet and Hsu, 2015).

This is the first study to our knowledge to assess whether compact development is associated with reduced gender disparities in spatial behavior by examining differences in the daily activity spaces of married heterosexual partners in Southern California using the 2012 California Household Travel Survey (CHTS). We hypothesize that households living in more compact areas with greater regional accessibility or neighborhood walkability have smaller, more centered, and more compact activity spaces overall compared to households in less compact areas, and that married pairs living in more compact areas have greater equality in the size, centeredness, and compactness of their activity spaces. We examine differences in these activity space measures across household regional accessibility and walkability levels for men and women in the sample to assess the relative influence of these two built environmental measures after accounting for household and socio-demographic factors.

# Literature Review

## Conceptualizing Activity Space

Activity space can be conceptualized as a geographic surface of all locations or areas individuals visit while fulfilling needs and desires. Each individual has a unique set of daily activities, must organize them in time and space, and faces constraints including the ability to perform activities, needing to be at a given location at a specific time to meet others, and time-space restrictions imposed by authorities (Hägerstrand, 1970; Horton and Reynolds, 1971). Previous studies identify differences in spatial behavior across socio-demographic groups and suggest that activity space measures provide a useful proxy of social exclusion or segregation (Järv et al., 2014b; Tan et al., 2017; Wang et al., 2015). From this perspective, a larger, more dispersed activity space could be desirable because it could potentially provide marginalized individuals access to a greater range of potential social and economic interactions and opportunities (Crawford et al., 2014; Sherman et al., 2005).

Other studies stress the importance of promoting more compact communities with high local accessibility to nearby amenities that can provide access to amenities and reduce vehicle travel and associated environmental pollution (Chen and Akar, 2016; Ewing and Cervero, 2010; Manaugh and El-Geneidy, 2012). From this perspective, a smaller, less dispersed activity space is preferable because it reflects more localized travel patterns since household needs can be largely satisfied within the nearby environment. Both approaches emphasize the importance of understanding how an individual's activity space intersects with local and regional accessibility.

## Gender Differences in Spatial Behavior

The gender division of domestic labor and household out-of-home activities has a strong influence on the spatial behavior of women. For instance, employed women shoulder more household responsibilities in childcare and maintenance tasks, face greater temporal constraints, and have shorter commutes than men due to their temporal fixities (Johnston-Anumonwo, 1992; Turner and Niemeier, 1997). They remain primarily responsible for out-of-home household-serving activities and travel and these responsibilities represent an important part of the gender division of domestic labor (Kwan, 2000). The space-time requirements of these activities greatly influence the employment status and commuting distance of women, and the space-time rigidity of some out-of-home activities are a daily source of stress (Kwan, 1999a). Women, regardless of their employment status, socioeconomic standing, and commuting distance, experience higher levels of spatial and temporal fixity compared to men, and the fixity of out-of-home activities such as passenger-serving trips may be the most important determinant of a person's activity-travel pattern (Kwan, 1999a).

The local residential environment also influences gender differences in spatial behavior. Hayden (2002) argues that housewives living in suburban areas tend to center their activities more in private spheres while their husbands conduct their lives in-between private realms and urban public spaces. Suburban development patterns can isolate women's public participation and burden employed women with second shift duty (Hayden, 1980; Little et al., 1988). That is, employed women take up the responsibility of unpaid household-related tasks after they complete their professional activities (Hochschild and Machung, 2012). Hayden (1980) and Pickup (1988) suggest a strategy to address gender inequality and advantage women who play dual roles in work and at home: enhancing land use mixing and surrounding opportunities (Hayden, 1980; Pickup, 1988). Recent studies extend this proposition by finding that compact mixed-use design, greater access to commercial establishments, and better transit service are associated with a more equitable household distribution of domestic labor and chauffeuring responsibilities (Boarnet and Hsu, 2015; Fagan and Trudeau, 2014).

Empirical studies of gender differences in spatial behavior, however, provide mixed results. Some indicate women have smaller activity spaces and lower accessibility to urban amenities than men (Fan and Khattak, 2008; Kwan, 2000, 1999b; Perchoux et al., 2014), but others find no significant difference in the size of activity spaces and access to amenities between men and women (Chen and Akar, 2016; Järv et al., 2014a, 2014b).

## Urban Form and Spatial Behavior

A growing body of empirical evidence provides insights into how features of urban environments influence accessibility and spatial behavior. Residents of more urbanized areas tend to have more compact activity spaces and to center their activity spaces on their residential neighborhoods (Buliung and Kanaroglou, 2006; Crawford et al., 2014; Perchoux et al., 2014). Likewise, suburban and sprawling development patterns are associated with larger activity spaces (Schönfelder and Axhausen, 2003). These differences seem to reflect that urban residents have greater accessibility than suburban residents because of the dense road networks in the urban core (Crawford et al., 2014).

Existing studies also examine the influence of the “D” variables on spatial behavior, including density, destination accessibility, and design (Ewing and Cervero, 2010). Residents of dense areas have smaller activity spaces (Chen and Akar, 2016; Fan and Khattak, 2008; Tana et al., 2016) and activity spaces and activity-travel patterns become more compact with increasing destination accessibility and decreasing distance between home and workplace (Järv et al., 2014a; Manaugh and El-Geneidy, 2012; Sherman et al., 2005). In contrast, however, Tana et al. (2016) found that individual activity space in Beijing increases with the number of retail stores around an individual’s home. In terms of street network design, Fan and Khattak (2008) found that activity spaces in the Greater Triangle area in North Carolina are smaller when street nodes are more dense and well connected (Fan and Khattak, 2008), but Tana et al. (2016) found in Chicago that activity spaces are smaller with decreased roadway density. Some of the differences observed across these studies could result from the use of simplified measures of urban form and a limited understanding of the associations between the between the “D” variables and spatial behaviors (Fan and Khattak, 2008; Tana et al., 2016).

# Data and Methods

## Survey and Sample Selection

This study examines the daily activity spaces of married heterosexual partners in Southern California using the 2012 California Household Travel Survey (CHTS), a statewide travel survey conducted by California Department of Transportation (California Household Travel Survey, 2012). We extracted our analysis sample from a subset of the 15,235 households in the counties of Los Angeles, Orange, Riverside, San Bernardino and Ventura that provided a travel diary for a 24-hour period. We retained households that reported weekday travel and included a married heterosexual couple in which both partners on the assigned survey day were between the age of 16 and 65 years old, traveled only by ground transportation including walking and biking, did not leave the state of California, started and ended their activities at home, visited at least two non-home places, and provided complete information regarding their genders, employment status, marital status, and the presence of child under 15 year-old in the households. Based on these criteria, 1,316 households including 2,632 married individuals were retained for the analysis.

We focused our analysis on married working-age heterosexual partners in order to compare gender differences in spatial behavior between matched husbands and wives assuming they at some level pool household and financial resources and make travel and activity decisions within a common household context. We examine only weekday travel since previous research indicates weekday travel-activity patterns can significantly differ from weekend patterns (Järv et al., 2014a), and we only included travel days with two or more activity locations because this is the minimum number required to generate the activity space measures described below.

Since the influence of built environmental factors is an important concern in our analysis, we utilized propensity score matching (PSM) to generate a subsample which helps address concerns raised by previous studies about endogeneity between the built environment variables and possible unobserved residential preferences when trying to estimate the influences of built environmental factors on travel and activity patterns (Boarnet and Crane, 2001; Cao and Fan, 2012; Handy et al., 2006). That is, households may choose a residential neighborhood based in part on the types of activity patterns they prefer. In our case, households which prefer to have smaller, more compact activity spaces may self-select into more walkable communities with a higher number of nearby destinations. Failure to account for this problem could lead to selection bias and possibly overestimate the effects of built environmental factors on spatial behavior (Cao et al., 2009; Fan and Khattak, 2008; Perchoux et al., 2014).

For PSM matching, treatment households were defined as households in the sample that lived in an area with a Walk Score of 70 or higher, which is considered very walkable with high accessibility to local destinations (Walk Score is described in greater detail below). We matched these households with control households with a Walk Score below 70 using the MatchIt package in R to calculate a propensity score for households based on a first-stage probit that included the presence of household children under 15 years old, household income level, the number of household vehicles, age, ethnicity, the possession of driver license, and employment status. Treatment households were matched with a control household when the radius for the propensity score was less than 0.01 (Boarnet and Hsu, 2015; Cao and Fan, 2012).

Treatment households not matched with a control household were dropped, resulting in a PSM sample including 217 treatment and 198 control households (Table 1). The PSM sample was similar to the full sample across most household and socio-demographic characteristics, but the PSM sample had higher rate of households with an employed wife and households living in an area with higher regional accessibility, or REDA (described in greater detail below). As expected PSM sample households had a higher Walk Score than households in the full sample (59 vs. 45, respectively).

**Table 1 Summary statistics of the independent variables for the weekday sample**

| Independent variables | Full sample | PSM sample |
|---|---|---|
| Sample size | 1,316 | 415 |
| Treated units | - | 217 |
| Control units | - | 198 |
| Household characteristics | | |
| The presence of kids under 15 years old (1/0) | 0.51 | 0.51 |
| HH income: $0-$49,999 (1/0) | 0.21 | 0.24 |
| HH income: $50,000-$99,999 (1/0) | 0.57 | 0.57 |
| HH income: greater than $99,999 (1/0) | 0.22 | 0.19 |
| The number of vehicles in household | 2.24 | 2.04 |
| Male household head's characteristics | | |
| Age | 48.91 | 47.47 |
| Hispanic (1/0) | 0.24 | 0.28 |
| Valid driver license (1/0) | 0.98 | 0.99 |
| Employed (1/0) | 0.85 | 0.87 |
| Female household head's characteristics | | |
| Age | 46.88 | 45.70 |
| Hispanic (1/0) | 0.25 | 0.27 |
| Valid driver license (1/0) | 0.94 | 0.94 |
| Employed (1/0) | 0.67 | 0.74 |
| Regional Employment and Destination Accessibility (REDA) | | |
| Low (1/0) | 0.26 | 0.19 |
| Low-medium (1/0) | 0.27 | 0.17 |
| Medium-high (1/0) | 0.28 | 0.29 |
| High (1/0) | 0.20 | 0.34 |
| Neighborhood Walkability (NW) | | |
| Walk Score | 44.72 | 59.47 |

## Measuring Spatial Behavior

There is no uniform approach identified in the literature for calculating an individual's activity space (Chen and Akar, 2016). Several techniques have been used to operationalize activity space, including standard deviation ellipse (SDE), which consists of an elliptical activity space boundary that is located on the mean center of activity patterns and constructed based on the bidirectional standard distances (Buliung and Kanaroglou, 2006; Perchoux et al., 2014), but this approach tends to extend into regions without household activities and likely overestimates geographic areas with which individuals are familiar (Schönfelder and Axhausen, 2003; Sherman et al., 2005). Therefore, we utilize the minimum convex polygon (MCP) approach which consists of the smallest possible polygon that includes all activity locations (Buliung and Kanaroglou, 2006; Chen and Akar, 2016; Manaugh and El-Geneidy, 2012; Sherman et al., 2005; Tana et al., 2016). The size, compactness and spatial concentration of MCP have been used to estimate the spatial dispersion of an individual's activity space (Manaugh and El-Geneidy, 2012; Perchoux et al., 2014).

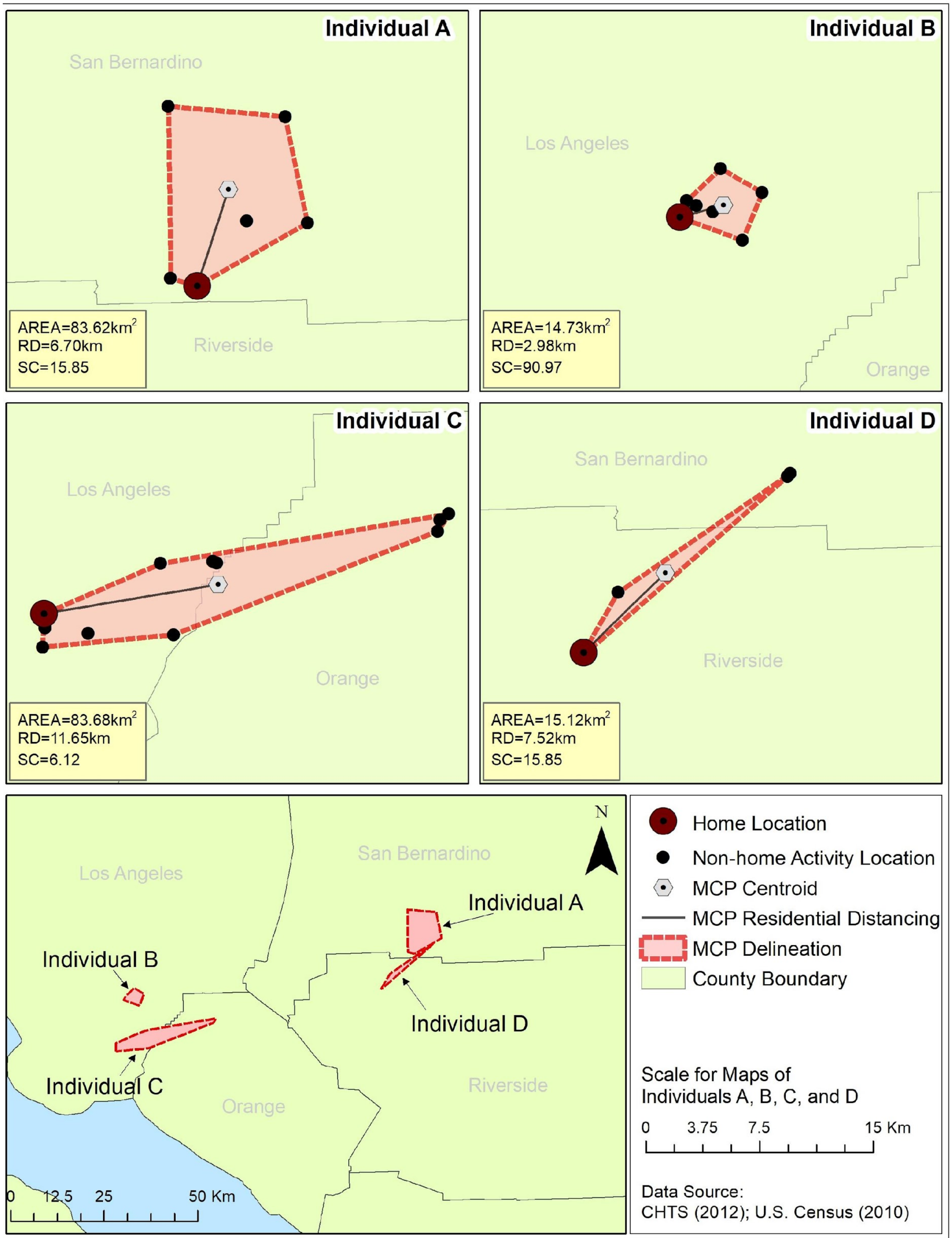
We utilized the Minimum Bounding Geometry tool for convex hull in ArcGIS 10.1 to create MCP measures for each individual in the sample. This procedure requires at least 3 unique activity locations that are not in alignment to generate an MCP boundary. Our key MCP activity space indicators include MCP activity space area ($MCP_{AREA}$), residential distancing ($MCP_{RD}$), and spatial concentration ($MCP_{SC}$) (Manaugh and El-Geneidy, 2012). Many studies have used activity space area ($MCP_{AREA}$) to illustrate the spatial extent which people have reached (Buliung and Kanaroglou, 2006; Fan and Khattak, 2008; Tana et al., 2016). It indicates people's spatial footprints and has been used to assess social exclusion across socio-demographic groups (Fan and Khattak, 2008; Schönfelder and Axhausen, 2003). Residential distancing ($MCP_{RD}$) represents the distance between the centroid of the activity space and the home location. This measure helps understand the degree to which people likely utilize nearby amenities and localize their activities close to their residence. Spatial concentration ($MCP_{SC}$) extends the spatial dispersal measure previously used by Manaugh and El-Geneidy (2012). They indicate activity space area and the traditional compactness measure (the ratio of area to square perimeter of activity space) may not fully explain the spatial dispersion of MCP activity space. Their spatial dispersal measure is developed to link area and compactness in order to better account for the dispersed degree. We defined spatial concentration ($MCP_{SC}$) based on Manaugh and El-Geneidy's formula as following:

$$MCP_{SC} = \frac{A_{max}}{MCP_{AREA}} \cdot MCP_{COMP}$$

$A_{max}$, the max MCP area in the sample

$MCP_{COMP}$, compactness, the ratio of $MCP_{AREA}$ to square perimeter of activity space

Figure 1 illustrates our three key MCP activity space indicators for four individuals. The activity spaces of Individuals A and B have similar compactness, but the activity space of B is more spatially concentrated than the activity space of A due to its smaller area. The activity spaces of Individuals A and C that have the same area, but A has greater a spatial concentration because of its compact shape. Although the activity space size and compactness are different for Individuals A and D, their activity spaces have the same degree of spatial concentration because the large activity space for A is evenly distributed in every direction whereas the small activity space for D is skewed and spatially dispersed. In this way, $MCP_{SC}$ is expected to provide a more refined measure since it identifies that a large but compact activity space (A) and a small but dispersed and skewed activity space (D) have the same degree of spatial concentration.




Note: MCP= minimum convex polygon, RD=residential distancing, SC=spatial concentration

**Figure 1 Comparison of the three key MCP activity space indicators for four individuals**

## Built Environment Indicators

Although in our preliminary analysis we assessed an extensive array of built environmental “D” factors which could potentially be associated with travel and activity patterns (Ewing and Cervero, 2010), consistent with previous studies, we found that accessibility variables were more consistently associated with our spatial behavior indices (Manaugh and El-Geneidy, 2012). Therefore, we focus our analysis on the influence of regional-level and local-level accessibility measures on the activity space patterns of our sample.

Our regional-level accessibility measure, which we call Regional Employment and Destination Accessibility (REDA), represents a gravity measure of accessibility to potential employment and destination locations in the region based on 2008 block group firm location data. It represents the inverse distance sum of firms weighted by total firm employees, with the distance from the grid cell of each household to other grid cells in the region in the denominator (Boarnet and Hsu, 2015; Houston et al., 2015). The grid cell is a 10-meter grid used for aggregating firm locations and avoiding outliers when households and firms were closely located. We used a gravity measure because we hypothesize that more distant destinations have less of an influence compared to closer destinations. In the analysis we stratified REDA into low, low-medium, medium-high, and high categories based on the 1st, 2nd, and 3rd quartiles of the variable based on the REDA of CHTS households over the SCAG region.

Our local-level accessibility measure, which we call neighborhood walkability (NW), is based on data obtained from Walk Score® (walkscore.com) for the residential location of sampled households. Walk Score® assigns walkability values between 0 to 100 to locations and classifies locations with a score of 70 or higher as very walkable. This measure employs a gravity-based model that awards points to amenities based on the distance to the amenities using walking routes. It designates maximum points to the amenities within 5 minutes of walking and no points to amenities with more than 30 minutes of walking. This measure accounts for the accessibility to the destinations and the street connectivity of the vicinity of a sampled household location (Carr et al., 2011). Several studies have validated the reliability of Walk Score (Carr et al., 2011; Duncan et al., 2011; Manaugh and El-Geneidy, 2011).

## Analytical Approach

We hypothesize that compact development is associated with greater gender equality in spatial behavior among married partners because it provides enhanced NW and REDA. We examine gender differences in the size, residential distancing, and spatial concentration of activity spaces using bivariate and ordinary least squares (OLS) models to assess the relative influence of household, socio-demographic, and accessibility factors on these measures of spatial behavior.

OLS models were used because the Breusch-Pagan test did not detect heteroscedasticity (Wooldridge, 2008). We transformed the three activity space measures ($MCP_{AREA}$, $MCP_{RD}$, and $MCP_{SC}$) to a normal distribution by using natural logarithm transformation. Our model assumption is that the dependent variable is a linear function of the independent variables and takes the following form:

$\ln(AS) = f(HH, SD, AC, REDA_C, NW)$

where f() is a linear function; AS is an activity space measure ($MCP_{AREA}$, $MCP_{RD}$, and $MCP_{SC}$), HH is a vector of household factors including presence of children, household income, and household vehicles; SD is a vector of socio-demographic factors for age, ethnicity, possession of valid drivers license, and employment status; AC is a vector of activities including the percent of work-related trips, shopping trips, and passenger-serving trips; $REDA_C$ includes categorical dummy variables indicating different levels of REDA based on the household's location; and NW represents Walk Score based on the household's location. The AC vector includes activity types which previous research indicates are frequently associated with gender differences (Boarnet and Hsu, 2015; Crane, 2007).

# Results

The analysis examines gender differences in the size, residential distancing, and spatial concentration of activity spaces, and the influence of factors including presence of household children, employment status, REDA, and NW. Bivariate results indicate males in the sampled households on average had larger activity spaces, greater residential distancing, and less spatial activity concentration compared to women in the sampled households (Table 2). Males who were employed or in households with 2 or more vehicles or with children had larger activity spaces and greater residential distancing, and their households on average had the greatest gender differences for these activity space indicators. Females on average had greater spatial concentration of activities, particularly those in households with a vehicle, households with children, and households with an employed male and unemployed female.

Average activity space size and residential distancing was the greatest for households located in areas with lower REDA and NW, and these indicators consistently decreased as REDA and NW levels increased (Table 2 and Fig. 2). Likewise, households in areas with the highest levels of REDA and NW experienced the highest levels of spatial concentration. Households in areas with the highest REDA and NW levels had on average the lowest gender difference in activity space size and residential distancing, and the greatest difference in spatial concentration. These patterns seem consistent with the fact that on average the difference in work-related activities, shopping, and passenger-serving activities between males and females in the sample decreased with increasing levels of REDA and NW.

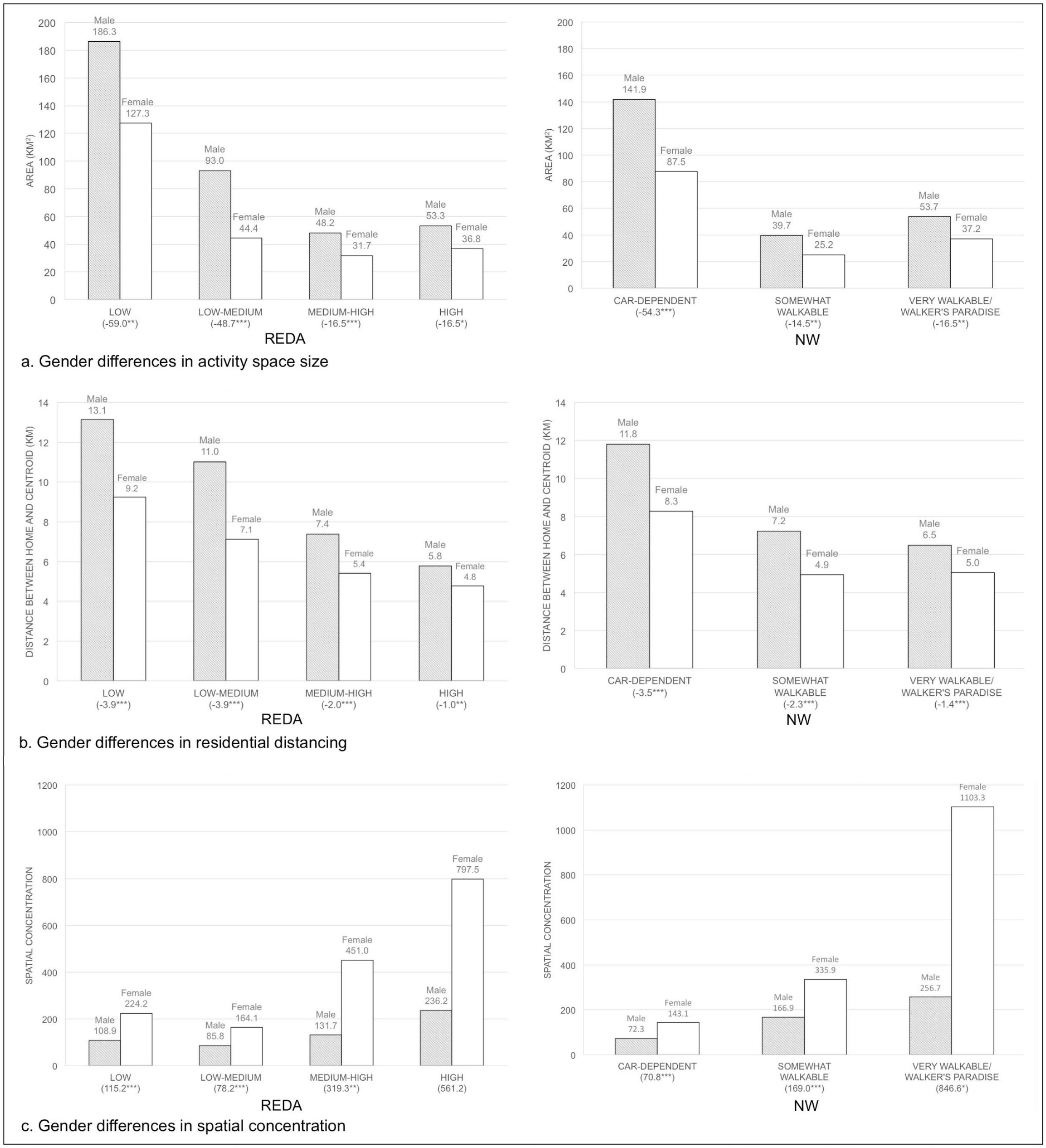
**Table 2. Mean gender differences in activity space indicators, by household, socio-demographic and built environment factors**

| | | Activity Space Size | | | | Residential Distancing | | | | Spatial Concentration | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | Male | Female | Diff. | Sig.[a] | Male | Female | Diff. | Sig. | Male | Female | Diff. | Sig. |
| All | 1,316 | 96.7 | 60.7 | -36.1 | *** | 9.5 | 6.7 | -2.8 | *** | 134.3 | 384.5 | 250.2 | *** |
| **Household vehicles** | | | | | | | | | | | | | |
| No vehicle | 18 | 37.4 | 21.2 | -16.3 | | 4.8 | 3.0 | -1.8 | | 422.9 | 550.0 | 127.2 | |
| 1 vehicle | 156 | 67.3 | 63.5 | -3.7 | | 7.3 | 6.2 | -1.1 | * | 274.4 | 616.6 | 342.2 | ** |
| 2 or more vehicles | 1142 | 101.7 | 60.9 | -40.8 | *** | 9.9 | 6.9 | -3.0 | *** | 110.7 | 350.2 | 239.6 | ** |
| **Presence of children** | | | | | | | | | | | | | |
| Paired heads w/ children | 671 | 113.6 | 65.2 | -48.4 | *** | 9.7 | 6.4 | -3.4 | *** | 139.4 | 403.3 | 263.9 | *** |
| Paired heads w/o children | 645 | 79.2 | 55.9 | -23.3 | *** | 9.3 | 7.1 | -2.2 | *** | 129.0 | 365.0 | 236.0 | |
| **Employment status** | | | | | | | | | | | | | |
| Emp M and F | 750 | 101.2 | 77.3 | -23.8 | *** | 9.7 | 7.6 | -2.0 | *** | 140.7 | 271.0 | 130.3 | ** |
| Emp M and unemp F | 374 | 107.4 | 30.8 | -76.5 | *** | 10.3 | 4.7 | -5.6 | *** | 87.2 | 719.8 | 632.6 | ** |
| Unemp M and emp F | 126 | 43.0 | 39.2 | -3.7 | | 5.6 | 6.3 | 0.7 | | 250.9 | 142.9 | -108.1 | |
| Unemp M and F | 66 | 88.7 | 81.1 | -7.6 | * | 10.7 | 8.8 | -1.9 | *** | 106.5 | 236.1 | 129.5 | ** |
| **REDA** | | | | | | | | | | | | | |
| Low | 338 | 186.3 | 127.3 | -59.0 | ** | 13.1 | 9.2 | -3.9 | *** | 108.9 | 224.2 | 115.2 | *** |
| Low-medium | 354 | 93.0 | 44.4 | -48.7 | *** | 11.0 | 7.1 | -3.9 | *** | 85.8 | 164.1 | 78.2 | *** |
| Medium-high | 362 | 48.2 | 31.7 | -16.5 | *** | 7.4 | 5.4 | -2.0 | *** | 131.7 | 451.0 | 319.3 | ** |
| High | 262 | 53.3 | 36.8 | -16.5 | * | 5.8 | 4.8 | -1.0 | ** | 236.2 | 797.5 | 561.2 | |
| **NW** | | | | | | | | | | | | | |
| Car-dependent areas | 699 | 141.9 | 87.5 | -54.3 | *** | 11.8 | 8.3 | -3.5 | *** | 72.3 | 143.1 | 70.8 | *** |
| Somewhat walkable areas | 358 | 39.7 | 25.2 | -14.5 | ** | 7.2 | 4.9 | -2.3 | *** | 166.9 | 335.9 | 169.0 | *** |
| Very walkable | 259 | 53.7 | 37.2 | -16.5 | ** | 6.5 | 5.0 | -1.4 | *** | 256.7 | 1103.3 | 846.6 | * |

Note: REDA=Regional Employment and Destination Accessibility, NW=Neighborhood Walkability

[a]Denotes the difference between the mean male measure and mean female measure is significant (paired t-test).

Significance: * p < .1, ** p < .05, *** p < .01.




Note: REDA=Regional Employment and Destination Accessibility, NW=Neighborhood Walkability

**Figure 2 Mean gender differences in activity space indicators, by built environmental factors**

Since bivariate results cannot disentangle the relative influence of factors on the size, residential distancing, and spatial concentration of activity spaces by gender, we constructed several OLS models to assess the relative importance of household, socio-demographic, and built environmental factors on the log transformed activity space indicators of males and females in the PSM sample (Table 3). Each additional household vehicle was associated with a 28% increase in activity space size, a 16% increase in residential distancing, and a 27% reduction in spatial concentration for males, but this factor was not significant in the female models. The presence of at least one child under 15 years old, however, was associated with a 76% reduction in activity space size, a 52% reduction in residential distancing, and an 87% increase in spatial concentration for females. In addition, employed females were associated with larger activity spaces, females who were Hispanic were associated with less residential distancing, and females with a valid driver license were associated with less spatial concentration.

For both genders, a higher percentage of work trips was associated with greater residential distancing and less spatial concentration. For males, a higher percentage of shopping or passenger-serving trips was associated with smaller activity spaces and less residential distancing. Although REDA dummy variables were not significantly associated with activity space indicators for males or females, households in areas with greater NW were consistently associated with smaller activity spaces, less residential distancing and greater spatial concentration. A ten unit increase in Walk Score was associated with a 12-18% decrease in activity space size, a 6-8% decrease in residential distancing, and a 12-13% increase in spatial concentration.

**Table 3. OLS analysis of factors associated with activity space indicators, by gender (PSM sample)**

| | Activity Space Size | | | | Residential Distancing | | | | Spatial Concentration | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Model 1 Male $\ln(MCP_{AREA})$ | | Model 2 Female $\ln(MCP_{AREA})$ | | Model 3 Male $\ln(MCP_{RD})$ | | Model 4 Female $\ln(MCP_{RD})$ | | Model 5 Male $\ln(MCP_{SC})$ | | Model 6 Female $\ln(MCP_{SC})$ | |
| | Coef. | Sig. | Coef. | Sig. | Coef. | Sig. | Coef. | Sig. | Coef. | Sig. | Coef. | Sig. |
| Intercept | 1.332 | | -0.875 | | -0.297 | | 0.652 | | 5.785 | *** | 5.795 | *** |
| **Household characteristics** | | | | | | | | | | | | |
| Presence of children (1/0) | -0.087 | | -0.763 | *** | -0.084 | | -0.529 | *** | 0.036 | | 0.874 | *** |
| HH income: $0-$49,999 (1/0) | -0.233 | | -0.310 | | -0.258 | | 0.140 | | 0.274 | | 0.046 | |
| HH income: $50,000-$99,999 (1/0) | -0.093 | | 0.026 | | -0.136 | | 0.106 | | 0.011 | | -0.090 | |
| Number of vehicles | 0.284 | * | -0.043 | | 0.161 | ** | 0.024 | | -0.268 | * | -0.061 | |
| **Head's characteristics** | | | | | | | | | | | | |
| Age | 0.057 | | 0.192 | * | 0.080 | | 0.055 | | -0.105 | | -0.121 | |
| Square age | -0.001 | | -0.002 | ** | -0.001 | * | -0.001 | | 0.001 | | 0.002 | |
| Hispanic (1/0) | 0.005 | | -0.286 | | 0.071 | | -0.312 | ** | -0.079 | | 0.264 | |
| Valid drivers license (1/0) | 0.846 | | 0.505 | | 0.384 | | 0.317 | | -0.613 | | -0.779 | * |
| Employed (1/0) | -0.292 | | 0.548 | ** | -0.065 | | 0.209 | | 0.097 | | -0.306 | |
| **Head's activities types** | | | | | | | | | | | | |
| % Work-Related Trips | 0.277 | | 0.281 | | 0.608 | *** | 0.469 | * | -0.799 | ** | -0.947 | * |
| % Shopping Trips | -1.084 | ** | -0.288 | | -0.494 | ** | -0.464 | * | 0.716 | | 0.776 | * |
| % Passenger-Serving Trips | -0.801 | * | -0.242 | | -0.600 | ** | -0.153 | | 0.622 | | 0.181 | |
| **REDA** | | | | | | | | | | | | |
| Low-medium (1/0) | 0.030 | | 0.345 | | 0.062 | | 0.141 | | 0.001 | | -0.404 | |
| Medium-high (1/0) | 0.002 | | 0.374 | | 0.028 | | 0.224 | | -0.063 | | -0.184 | |
| High (1/0) | 0.012 | | 0.432 | | -0.115 | | 0.120 | | 0.006 | | -0.122 | |
| **NW** | | | | | | | | | | | | |
| Walk Score | -0.012 | ** | -0.018 | *** | -0.006 | ** | -0.008 | *** | 0.013 | *** | 0.012 | ** |
| Sample size | 415 | | 415 | | 415 | | 415 | | 415 | | 415 | |
| Breusch-Pagan test | 0.60 | | 0.17 | | 0.14 | | 0.35 | | 0.30 | | 0.76 | |
| Adjusted $R^2$ | 0.04 | | 0.11 | | 0.11 | | 0.14 | | 0.07 | | 0.13 | |
| P-value of F-statistic | 7.66E-03 | | 2.25E-07 | | 1.40E-07 | | 3.54E-10 | | 1.58E-04 | | 4.74E-09 | |

Note: REDA=Regional Employment and Destination Accessibility, NW=Neighborhood Walkability
Significance: * $p < .1$, ** $p < .05$, *** $p < .01$.

## Discussion

Our results support compact development policies by demonstrating that households living in areas with higher regional and local accessibility, or walkability, have smaller activity spaces, less residential distancing, and greater spatial concentration. Multivariate regression results indicate a ten unit increase in Walk Score was associated with a 12-18% decrease in activity space size, a 6-8% decrease in residential distancing, and a 12-13% increase in spatial concentration. These patterns are consistent with previous studies which suggest residents of more urbanized areas focus their travel and activities near their residence (Buliung and Kanaroglou, 2006; Chen and Akar, 2016; Crawford et al., 2014; Perchoux et al., 2014), and suggest that compact communities provide valuable access to nearby amenities and are associated with reduced vehicle travel and related air pollution. During a time when polices to reduce greenhouse gas emissions are increasingly under attack at a federal level in the United States, our findings should signal to local, regional, and state policy makers that compact develop strategies represent a step in the right direction.

Our study is also the first to our knowledge to suggest an exciting possibility: that compact development provides an enhanced local environment that could not only help achieve the primary policy outcome of promoting reduced vehicle travel and associated emissions but could also have an impactful secondary outcome by helping alleviate stubbornly persistent gender inequalities in the division of out-of-home responsibilities. Consistent with previous studies which identify gender differences in spatial behavior (Fan and Khattak, 2008; Perchoux et al., 2014; Tana et al., 2016), we found that overall men tended to have larger activity spaces than women, and women were more likely to center their activities near their residential locations and have spatially concentrated activities. However, overall differences between men and women in the sample were reduced with increasing levels of accessibility for two of our activity space indicators. For instance, the absolute gender difference in the activity space size was 72% lower for those in areas with high regional accessibility compared to those in areas with low regional accessibility, and the difference in residential distancing was 74% lower for those in areas with high regional accessibility compared to those in areas with low regional accessibility. We observed a similar pattern for walkability.

These patterns are consistent with our hypothesis that compact development provides married couples greater flexibility in how to divide household out-of-home activities by making destinations more convenient and lowering the overall spatial fixity of these activities. In fact, we found greater parity in work-related activities, shopping, and passenger-serving activities between men and women living in areas with the highest accessibility levels. These findings are consistent with previous research which suggests that compact mixed-use design, greater access to commercial establishments, and better transit service are associated with a more equitable distribution of domestic labor and chauffeuring responsibilities (Boarnet and Hsu, 2015; Fagan and Trudeau, 2014). The influence of built environmental factors on gendered spatial behavior, however, could partially be the result of married couples choosing to live in a neighborhood because its location and composition supports how they want to divide household travel and activity tasks. We addressed this potential residential selection bias in our analysis by implementing a PSM sampling technique that allowed us to more directly isolate the influence of regional and local accessibility on spatial behavior.

Policy makers should proceed cautiously, however, with the recognition that not all compact, accessible areas are created equally and that travel and activity space behavior is influenced by a neighborhood's dominant travel mode. In addition, previous research suggests the design and influence of compact development can vary greatly across socio-demographics and by neighborhood (Houston et al., 2015). Future research and planning efforts should carefully consider which aspects of compact development and increased accessibility will be most effective for a given local context.

Although results suggest implementing compact development could help women overcome spatial barriers and enjoy greater spatial freedom in urban space compared to men, important differences persist. For instance, as Walk Score increased by ten units, the activity space size of men and women decreased by 12% and 18%, respectively. In addition, although the spatial concentration of the activity spaces for men and women both increased as expected with increasing levels of accessibility, the concentration of male activities was 117% greater in areas with high REDA compared to those in areas with low REDA but the concentration of female activities was 256% greater in areas with high REDA compared to those in areas with low REDA. This suggests that, consistent with findings by Crane (2007), men and women seem to respond differently to changes in urban design features (Crane, 2007). Women may be more likely than men to utilize nearby services when local opportunities become more readily available.

Socio-demographics, activity types, and car accessibility also played an important role in gender differences in spatial behavior. The presence of children was strongly associated with more constrained activity space and more activities closer to home for women but not for men. As women undertook more shopping trips than their male counterparts, they were more likely to center their activities closer to their residence relative to their husbands. These results imply that, consistent with previous research, women continue to experience greater spatial constraints partly due to the responsibility for household-related tasks (Johnston-Anumonwo, 1992; Little et al., 1988; Tivers, 1988; Turner and Niemeier, 1997).

Even though we identify how more accessible, compact communities could provide opportunities for greater gender equality, we did not examine other important factors including the distribution of at-home domestic labor or gender stereotypes and constraints that could exacerbate gender disparities (Hayden, 2002). Future research is needed to investigate these factors, and potential disparities in spatial behavior for a wider range of household types and family structures. We found employed married women were most likely to have larger and less compact activity spaces than their husband, but to what extent do these women remain burdened by second shift duties when they arrive home after work (Hochschild and Machung, 2012; Johnston-Anumonwo, 1992)? In addition, future research is needed to assess alternative approaches for delineating the complexity of real-world travel-activity patterns and their relationship with the underlying urban structure (Li and Tong, 2016).

Our REDA and NW measures are place-based accessibility indicators based on residential locations, but further research is needed to assess the influence of person-based accessibility measures on gender equality in spatial behavior given such techniques can be more “gender-sensitive” because they can account for spatial-temporal and scheduling constraints which impact an individual’s ability to reach destinations (Kwan, 1998). In addition, our REDA and NW measures are distance-based and results could differ by time of day and geographically if variation in travel time and traffic conditions were taken into account. Our understanding of gender differences in spatial behavior could also be expanded by analyzing multi-day travel and activity patterns and the influence of built environmental factors near other anchor locations such as the workplace and at different spatial scales (Fan and Khattak, 2008; Spears et al., 2016).

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