Chasing sustainability: Do new TOD residents adopt more sustainable modes of transportation?

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ABSTRACT

It is suggested that one of the solutions for mitigating the detrimental effect of motor vehicles on society is to implement Transit-Oriented Development (TOD). This type of development is intended to reduce automobile use and urban sprawl as well as to provide communities with more socially, environmentally, and economically sustainable neighborhoods that offer a variety of mobility choices. This paper attempts to find out whether new TOD residents adopt more sustainable modes of transportation after their relocation. The analysis determines which factors influence travel mode switching decisions by specifying a multilevel multinomial logistic regression model. Data for the analysis are drawn from a travel behavior survey conducted on residents in seven different North American TODs in 2013. Our results show that TOD newcomers adopt more sustainable travel modes for amenities and leisure trips, whereas they are less likely to do so for work and shopping trips. To encourage more sustainable travel modes, our findings suggest that transit incentives coupled with workplace parking charges need to be considered. Awareness of the environmental impact of each travel mode, walkability of the neighborhood and availability of various destinations as well as proximity to transit stops are factors that increase the probability of switching to a more sustainable mode of transportation for new TOD residents. However, larger household size and becoming a homeowner, as well as the addition of a new car, have a negative impact. Findings from this research provide new insights into TOD planning and its link to travel behavior that can be of benefit to planners, engineers and policy makers adopting this approach of development with the goal of mitigating car usage.

Keywords: Transit-oriented development, travel mode choice, sustainable, multilevel multinominal logistic regression

INTRODUCTION

Urban problems such as congestion, sprawl and greenhouse gas emissions caused by 20th century land use practices have motivated local governments to address these challenges by planning more sustainable neighborhoods. Transit-oriented development (TOD) is one approach that claims to help reduce automobile dependency by making other modes more accessible and available, by reducing distances between trip origins and destinations, and by designing a more enjoyable walking environment (*1; 2*). TOD is a widely used term that refers to a municipal development strategy aiming to create accessible, diverse, dense and compact communities that are socially, environmentally, and economically sustainable. In other words, it is a development strategy designed to reinforce mass transit use for home-to-work trips, as well as the use of active modes, such as walking and cycling, for daily errands (*3*). The use of active modes is facilitated by the fact that a TOD's area can be covered within a ten-minute walk. TODs are most commonly built surrounding rail stations and attempt to develop these places into visually appealing and multi-functional areas. As an alternative to being developed around rail, TOD can also be built around other major public transportation nodes such as bus rapid transit stations, but this occurs less frequently. TODs' potential benefits are intented to reach the principles of sustainable development.

While studies have long found that households located near rail stations have higher rates of transit use compared to those located farther away (*4*-*6*), to our knowledge there are no studies determining whether new TOD residents alter their habits and start using more sustainable modes of travel. This paper attempts to understand the factors leading to changes in individuals' daily mode choices after they have relocated to a TOD compared to their travel mode choices at their previous residential location. To understand these changes, this analysis uses a multilevel multinomial modeling technique.

LITERATURE REVIEW

Travel behavior has been intensively studied over the last decades. The previous studies presented in Table 1 demonstrate that travel mode decisions are based on multiple influential factors, such as socio-demographics, built environment characteristics, and individual' attitudes.

Household and individual socio-demographics characteristics strongly influence travel mode decisions (*7; 8*). According to one study, men are more likely to switch to modes other than private cars, but women are more likely to ride public transit than men (*9*). Another study shows that age is often positively associated with the use of motorized vehicles and usually negatively related to walking and cycling (*10*). However, the observed relation is different for seniors. For example, Hensher (*11*) confirmed the presence of a modal change, which may partly be the result of losing their driver's license, starting at the age of 65. The change goes first from being the driver of a car to being a passenger, and then to using transit. Lower income is usually associated with higher transit use, even when accounting for self-selection (*12*). Level of education was also found to be significant in affecting travel mode choice, but findings from the literature are mixed in this case, since education can be an indicator of either poverty or different social-environmental awareness. De Witte, Machanis and Mairesse (*13*) found that highly educated people are far more likely to commute by car, while commuters belonging to lower educational level are more likely to use the train. Alternatively, Carse et al.'s (*14*) results suggest that lower level of education is linked more to car use for leisure, shopping, and short-distance commutes.

Possession of a driver's license and access to a car also have a significant effect on changes in mode use (*15*). In addition, individuals with more complex commutes (e.g. multiple stops such as dropping off children) or with busy agendas usually prefer to use cars (*16-18*).

Characteristics of the built environment also play a prominent role in determining the favored travel mode choice of individuals for each type of trip. However, individuals with an inclination to commute using public transportation or active modes also tend to locate themselves in walkable neighborhoods with sufficient access to transit (*4; 19; 20*). This observed tendency is known as residential self-selection. Controlling for self-selection is important in travel mode choice studies. It can be accomplished by asking which criteria people have considered when choosing their current neighborhood (*4; 12; 19-22*). This control avoids to over- or under-estimate the built environment's characteristics in the analysis (*20*). The most studied built environment characteristics are density, land use, pedestrian-oriented design, and accessibility to multiple services (See Table 1). In short, empirical research has found that there is a higher use of active modes and transit in neighborhoods that are more walkable, have a higher density, and a diverse land use mix (*23; 24*).

Other studies argue that the use of non-motorized modes is more likely where there is more paid parking (*15; 24; 25*). For example, in his research on the Chicago Transit Authority's (CTA) rapid transit system, Chung (1997) found that parking availability was one of the most significant factors explaining ridership, while Lari et al. (*26*) observed that transit fare incentives coupled with higher parking prices increased ridership. For Carse et al. (*14*), free workplace parking and commuting distances were strongly related to car use for commuting trips. As Kingham et al. (*25*) made clear, all these studies suggest that increasing the cost of using a car results both in a shift to alternative modes and in a choice to live closer to one's workplace. Longer trips also affect the propensity for transit and car use (*27; 28*). Nevertheless, access to transit from home is also a criterion taken into account in studies on travel mode choices (*27; 29*). Finally, satisfaction with the mode used for diverse trip purposes, combined with pre-existing attitudes or perceptions towards different travel modes, influence mode switching (*21; 30; 31*).

[Insert TABLE 1 here]

DATA AND METHODOLOGY

The main objective of this study is to understand and identify the factors that affect TOD newcomers' decisions to adopt modes of transportations that are either more or less sustainable after relocation. To achieve this objective, this study uses a multilevel multinomial logistic regression to compare the travel mode choice of survey respondents for two time periods: before and after moving to a TOD, while controlling for socio-economic, built environment and self-selection variables.

Data

The data used comes from a comparative survey conducted by an inter-disciplinary research group: Transportation Research at McGill (TRAM) in Montreal, Canada, in collaboration with Delft Technical University in the Netherlands. The survey was completed by 586 people from seven different TODs: Rosslyn (Arlington), Virginia, USA; South Orange, New Jersey, USA; Berkeley, California, USA; Mockingbird Station and Downtown Plano station, Dallas, Texas, USA; Equinox station, Toronto, Ontario, Canada; and Joyce-Collingwood station, Vancouver, British Columbia, Canada. TOD study locations where chosen based on a review of the literature. 5000 addresses within an 800-meter buffer were randomly purchased from private companies for each American TOD. The buffer had to be increased to 1600 meters for each Canadian TOD in order to obtain 5000 addresses from Canada Post. While this paper employs the term "relocation to a TOD", readers should keep in minds that, for Canadian respondents, it is actually a relocation "near or in" a TOD.

In the fall of 2013, postcards were then sent to the selected addresses to invite individuals to participate in the survey, and prizes where used as incentives. Not all of the postcards were successfully delivered, with several dozen having been returned to the sender. While many postcards were returned to the sender, we expect that many more American ones should have been returned, but were not delivered to our Canadian return address as it would have been considered international mail. Due to financial constraints we were unable to send a second round of postcards to remind TOD residents to participate in the study. Therefore, determining an actual response rate is not possible. A conservative estimate of response rates, assuming all cards were delivered, should be 2 % for Rosslyn, 1.4% for South Orange, 3% for Berkeley, 1.5 % for Mockingbird Station, 1.7% for Downtown Plano station, 1.7% for Toronto, and 2.2% for Vancouver, which is an average of 83.7 mail surveys by TOD. Although response rates are low, this is based on the assumption that all cards were delivered, which cannot be true due to the returned mail. However, fortunately the overall number of participants is acceptable to conduct statistical analysis.

To participate in the survey, participants where directed to the online survey which included general questions to capture information such as the respondents' previous and current utilitarian and non-utilitarian modes, individual socio-demographic characteristics, as well as previous and current home location, and current work location. The survey included a series of guided questions to capture detailed information about different aspects of their trip as well as their levels of satisfaction. Finally, the survey was designed to capture seasonality in travel choices, allowing individuals that switch modes to provide the details of their trip during different weather conditions.

From the total collected data, 108 surveys were rejected due to incompletion. The final dataset included information from 478 participants. Spatial measures were calculated for each respondent using secondary data sources in a geographical information system. For instance, the population density by zip code (postal code in Canada) of each respondent's home and previous home was calculated from data on population and land use from the American and Canadian censuses. Shapefiles of sidewalks and amenities for the seven TODs analyzed were not available to create walkability indices such as the one presented by Frank et al. (*32*), Kuzmyack et al., or Krambeck (*33*). Consequently, the Walk Score of each respondent's current and previous addresses were used as a proxy to neighborhood diversity and local accessibility using the online Walk Score tool (*34*). This tool, which attributes a "Walk Score" between 0 and 100 to addresses, has been demonstrated to be valid for estimating neighborhood walkability by measuring access to different facilities (*35*). For each address, the tool analyzes hundreds of walking routes to nearby amenity categories such as retail, recreation and leisure opportunities. Points are awarded based on the distance to amenities in each category. Amenities within a five minutes walk (0.25 miles or 0.4 km) are given maximum points. The tool uses a decay function to attribute points to more distant amenities, but stops giving points for attractions beyond a 30-minute walk. It also measures pedestrian friendliness by analyzing variables such population density and block length. Data sources used by this tool include Google, Education.com, Open Street Map, Census and

Localeze (*34*). In a study comparing the explanatory power of four walkability indices, Manaugh and El-Geneidy (*36*) found that the Walk Score index explains the variation in walking trips to various destinations as well as other walkability indices used in the literature. In addition, differences in the explanatory power amongst the examined indices were negligible.

The resulting dataset was transformed into long format, in order to be able to use the trips' purposes as the unit of analysis instead of the respondents' (wide format). "In the wide format, the individuals observed are the observations of a dataset, while the variables are their characteristics" (*37*). In contrast, in the long format, the observations are the individuals *usually at a specific point in time* – the trip purpose in our case – and the variables are the observed characteristics (*37*). The benefit of this transformation is that it increased the number of observations from 478 to 2459, thus allowing us to perform more advanced statistical analyses.

Six different trip purposes are analyzed in this study: (1) trip to work; (2) to the gym, to indoor recreation, or to a community center; (3) to a service provider (bank, post-office, medical-clinic, pharmacy, etc.); (4) to a café, bar, or restaurant; (5) to the main shopping street or mall, and (6) to entertainments (movie, theater, gallery, etc.). It is important to consider that the number of trip purposes varies for different survey respondents. For instance, some of survey participants have only four different types of trips while others provided information for each of the six trips. People reported their primary mode of transportation to reach the above-mentioned destinations before and after moving to a TOD. A primary mode of transportation refers to the type of transportation taken for the longest portion of a single trip. Responses were recoded into three different categories: automobile (as a driver or passenger), public transit, and active modes such as walking and cycling. Next, three more dummy variables were created to classify the different travel mode choices made by the respondents once they had moved to a TOD: (1) a switched to a less sustainable mode of transportation, (2) no switch, and (3) a switched to a more sustainable mode of transportation. Figure 1 shows how these variables were generated.

[Insert FIGURE 1 here]

Methodology

This study employs a multilevel multinomial logistic regression model that controls for correlations between responses from individual survey respondents; it is a mixed linear model with linear predictors (*38*). This type of model is used when the dependent variable exhibits more than two categories that cannot be ranked, and when the dataset is organized on more than one level or structure (*39; 40*).

The present database is organized by different structures represented by the different trip purposes of the survey respondents (each individual is repeated by the number of different types of trips they reported). A likelihood ratio test was used to determine if the multilevel multinomial logistic regression model is more appropriate for the analysis than regular multinomial logistic regression model. The multilevel model allows us to accurately control for correlation between an individual's responses and provides a fit for the analyzed data that is more appropriate for the type of data used than a regular multinomial logistic regression model. In other words, having more than one observation coming from the same person causes a bias in the output if the regular multinomial model is used. Controlling for this bias is achieved through the multilevel modeling technique, where the software understands that some of the data are obtained from the same person. In addition, we also tested having two levels, individual and neighborhood (in this case the TOD), yet the neighborhood was not found to be significant. Therefore, only one level, which is the individual, is used in our analysis.

In this study, the unordered categorical dependent responses refer to the type of switch made by the respondents for their various trip purposes, and are categorized as: *switch to a more sustainable mode of transportation*, *switch to a less sustainable mode of transportation, and no switch*. In the multilevel multinomial logit model used for this analysis, the *no switch* category represents the reference (base outcome). Table 2 defines the variables used in the analysis and tested in the model. Only variables with an asterisk (*) are kept in the model. The others were eliminated from the study because they were not significant (Likelihood ratio test) and/or because they were highly correlated (with a Person coefficient greater than 0.5) with other variables. For example, when we tested the relationship between socio-demographic variables and the probability of switching either to a more or less sustainable mode of transportation, except for the household size, all other relevant socio-economic variables according to the literature revealed to be insignificant. This may indicate that the initial choice of a travel mode is partly conditioned by socio-demographic characteristics, as previously shown in the literature. However, the decision to switch from one's original mode is not. Also, the final model does not account for modal time and cost of each trip.

[Insert TABLE 2 here]

RESULTS

Descriptive Analysis

Before their relocation, a large proportion (51.71%) of trips made by respondents were already being made using sustainable modes of transportation. Alternatively, 49.29% of the trips were made by automobile (See Table 3). The high presence of people already travelling by sustainable modes indicates the presence of self-selection occurring in the sample. However, the results from the descriptive statistics suggest a positive change in the travel choices of people once they have relocated to a TOD, despite the fact that, on average these respondents previously had more sustainable travel behavior habits than the average individual (They used their automobile only for 49.29% of their trips). The proportion of people choosing to travel by automobile is reduced, while the proportion of people commuting by foot rises significantly (Table 3).

The TODs included in this study are built around rail stations, but findings show that, contrary to what one would expect, the proportion of people using public transit remains practically the same compared to the use at respondents' previous home locations. Despite these results, TODs do have a strong effect on a switch to active modes for trips to reach amenities.

[Insert TABLE 3 here]

In total, while 45% of respondents switched to a more sustainable mode, 39 % switched to a less sustainable mode for at least one of their trip types after moving to a TOD. But, 29% of the respondents did not modify their travel mode choice habits after residential relocation to a TOD.

Table 4 presents the percentage of switches to a more sustainable mode of transportation, sorted by trip purpose. Overall, 20.41 % of the trips in the study use a more sustainable mode, while 17.36% use a less sustainable mode compared to the mode they used in their previous residential location. The difference in percentage between these two is statistically significant at a

98% confidence interval. This overall improvement is due to a positive shift in the proportion of sustainable travel mode choices made when travelling to different amenities. Indeed, the travel mode choice used to reach neighborhood amenities ((1) gyms, (2) service providers, (3) bars/cafés/restaurants or (4) any other entertainment destinations) has improved, in the sense that a more sustainable travel mode is chosen by people after they moved to a TOD. Independent sample t-test results show that there is a statistically significant difference between the percentages of people who switched to a more sustainable travel mode, compared to those who made the reverse decision for the four previously mentioned trip to amenities. The number of shoppers switching to a less sustainable mode of transportation is not significantly greater than the number of shoppers who switched for a more sustainable mode according to an independent t-test. However, for commuting trips, a statistically significant independent sample t-test shows that a higher proportion of people choose to use a less sustainable mode of transportation after their move. A careful analysis allows us to minimize the importance of the above-mentioned results, since about 30% of the workers who have switched to a less sustainable mode had switched from walking to using transit. While less sustainable than walking, using public transit is still considered to be a more sustainable mode of transportation than travelling by car (*41*).

[Insert TABLE 4 here]
[Insert TABLE 5 here]

Multilevel Multinomial Logistic Regression

Table 5 displays the results of the multilevel multinomial logit regression. It determines the probability of an individual switching to a more or to a less sustainable mode of transportation. The model uses the *no switch* variable as the reference group. We used relative-risk ratios (RRRs) to further interpret the effect of each variable. For a unit change in the predictor variable, the relative-risk ratio of outcome *X* relative to the referent group is expected to change by a factor of the respective parameter estimate given the variables in the model are held constant. An RRR greater than or less than one shows an increase or a decrease in probability, respectively.

The estimated variances of the two random effects in the model are 2.93 and 3.06, implying a standard deviation of 5.81 and 6.07. Thus, a 1-standard-deviation change in the random effect amounts equals 333.6 and 432.6 change in the relative-risk ratio. The effect is both practically significant and from the output, statistically significant. The covariance is estimated to be -0.32, therefore the estimated correlation equals to -0.107.

Switching to a More Sustainable Mode of Transportation vs. Not Switching

As expected, several factors are negatively associated with a switch to a more sustainable mode of transportation, including household size, access to free workplace parking, walking time to the grocery store, as well as walking time to the closest transit station. In contrast, an increase in Walk Score, access to reduced or free transit fare, and the awareness of the environmental impact of the chosen travel mode used are positively associated with a switch to a more sustainable travel mode. The probability of switching to a more sustainable travel mode versus not switching is 50% lower for people with free workplace parking; 26% lower for each additional member in a household; 1% lower for each additional minute separating the respondent's house from his preferred grocery store, and 8% lower for each additional minute separating the respondent's house from the nearest transit stop. It appears that proximity to transit within TODs makes little difference in the probability of adopting a sustainable mode of transportation relatively to the other factors studied. The probability of switching to a more sustainable travel mode versus keeping the same mode is about two times greater if the Walk Score of the current address is higher than the previous one; 1.71 times greater for a person with access to a reduced or free transit fare, relative to someone who does not have one; and 2.45 times greater for a person aware of the environmental impact of each mode, relative to someone who is not.

People who have decided to relocate to a TOD partly in order to be closer to public transit or because they needed less housing space are respectively 2.39 and 4.37 times more likely to use a more sustainable travel mode after their relocation than the referent group. However, people who have moved due to incapacity to afford their previous residence are 85% less likely to adopt a more sustainable travel mode, as compared to those who did not switch modes. These results might be explained by the fact that these people did not modify their travel mode habits as they may already have used either public transit or another active mode due to their financial situation. *Ceteris paribus*, the respondents who chose their current location based on the neighborhood's walkability are almost twice as likely to switch to a more sustainable mode versus keeping the same mode, relative to those who did not choose their neighborhood based on that criterion. The desire to use public transit more frequently is negatively associated with a positive change in travel mode. The probability of switching to a more sustainable mode of transportation versus not switching is 47% lower for people who have such desires, relative to those who do not. This finding may indicate that the desire to commute more by public transit does not come from drivers, but rather from people who already use transit or walk and will continue to do so.

Finally, shopping trips to a "main street" or mall are negatively associated with a sustainable change in travel mode. Relative to all other trip purposes studied, the probability of switching to a more sustainable mode versus not switching is 63% lower when respondents travel to the main shopping street or mall. This suggests that people are not willing to switch to a more sustainable mode for this particular trip type. This result, however, is not unexpected, as often shopping includes carrying bags, and stores and malls usually provide inexpensive or free parking facilities.

Switching to a Less Sustainable Mode of Transportation vs. Not Switching

The acquisition of a new vehicle, becoming a new homeowner and having access to a free parking spot at work all increase the probability of switching to a less sustainable mode of transportation. In contrast, an increase in Walk Score, the possession of a free or reduced transit fare, and an awareness of the environmental impact of the travel mode used reduce an individuals' likeliness to switch to a less sustainable mode. Regarding vehicle ownership, the relative risk of switching to a less sustainable mode of transportation versus keeping the same travel mode is 2.95 times greater for each additional vehicle acquired after the relocation to a TOD; 2.15 times greater if the respondent becomes a homeowner; and 3.73 times greater if a free parking spot is provided at his or her work. This finding suggests that "settling down" in life negatively impacts the propensity of switching to sustainable travel modes. However, an increase in Walk Score lowers the probability of adopting a less sustainable mode by 76%, and reduced or free transit fare by 74%. In contrast, being conscious of the environmental impacts of varying modes reduces this propensity by 62% in comparison with someone who is not aware of the impact, if all other variables in the model remain constant. Finally, in this model, shopping trips and work commutes are positively associated with switching to a less sustainable mode of transportation. The former increases the risk of switching to a less sustainable mode, versus not switching by 1.59 times, while the latter increases the risk by 2.87 times.

Despite the fact that socio-economic characteristics, parking access, transit incentives and neighborhood preferences have a strong effect on mode switching, the descriptive analysis and the model presented in this paper reveal that TOD can encourage the use of more sustainable travel modes, even if it is not for every type of trip, by providing good access to transit and a walkable environment with desired destinations.

CONCLUSION

Do TODs actually lead to less driving and, therefore, more sustainable transportation behavior? The results of this study make clear that individuals alter their travel modes after relocating to a TOD. TODs encourage more sustainable mode choices; at least 45% of the respondents switched to a more sustainable mode of transportation for one of their trip types after relocation. This finding shows that the implementation of TODs can reduce automobile use. However, our findings suggest that this effect only applies for trips to certain amenities.

The number of respondents who commute to work by automobile increased after their relocation to a TOD. This finding is alarming, but not surprising as Chatman (*1*) recently reported that rail access is not the principal factor explaining lower rates of auto ownership and the probability of commuting by automobile in TODs. Fortunately, results from the multilevel multinomial logistic regression offer a solution for solving this disappointing reality; transit incentives coupled with charging for parking or setting a limit on the number of free parking spots at work need to be considered. Accordingly, the former reduces the risk of switching to a less sustainable mode of transportation while increasing the probability of switching to a more sustainable mode. In contrast, by reducing free parking availability, the latter could positively alter travel mode choices. Regarding these findings, local governments can reconsider their parking policy requirements at some job locations. Revised by-laws could potentially contribute to reduce automobile commuting in cities, and not just for TOD residents. In addition, while the TODs analyzed are supposed to be well designed, implementing more measures encouraging alternative transportation mode-use to transit stations as well as reducing the number of free parking available may also reduce the number of TOD residents that commute to work by car. Regarding shopping trips to a main street or to a mall, results of the model reveal that people are less likely to adopt more sustainable modes of transportation for shopping trips after their relocation to TOD. Therefore, in the short-term, policies, especially those related to planning the implementation of TODs, need to emphasize actions effecting commuting habits, while changes in travel mode choice for shopping trips and consumer behaviors should be further analyzed to determine which factors would promote the use of active modes of transportation and transit for shopping trips.

Regarding trips to amenities (gyms, service providers, restaurants and entertainments), results from this study show that many actions could be taken to reduce automobile usage among residents. First, planning strategies need to focus on denser mixed-use developments with pedestrian- and cycle-friendly infrastructure, and should offer better access to various amenities. Indeed, survey respondents in this study appeared to temporally adjust their modal choices to their new spatial setting. For example, moving to an area with a higher Walk Score compared to their previous residential location doubled the likelihood of switching to a more sustainable mode. Second, since individuals who are conscious of the environmental impacts of their chosen mode are also more likely to switch to more sustainable modes, policies that promote the benefits of sustainable modes need to target these residents, while educating and informing individuals. This would allow people to make more informed travel mode choices and could increase the number of pro-environmentally inclined individuals, who are more likely to switch to sustainable modes. However, it should be recognized that without suitable infrastructure, this type of policy cannot be fully successful. Yet, TOD implementation is one method of overcoming the travel option deficit in cities. They enable people who prefer to use transit, cycling and/or walking to do so more often. In addition, findings from this research can also be of interest to transportation planners and policy makers. It appears that transit agencies should consider how to accommodate and accompany people throughout their lives as well as how to increase users' transit ridership retention since lifecycle changes have been shown to negatively impact the propensity to use sustainable travel modes even in TODs.

More generally, future research that assesses travel mode switching for utilitarian and non-utilitarian trips in TODs need to account for the travel time and cost needed to reach desired destinations. The absence of such variables is a limitation of this study. Additionally, our research fails to explain mode specific factors that encourage sustainable switching due to sample size limitations. Nevertheless, the increased proportion of people using active modes of transportation for reaching diverse amenities after relocating to a TOD is promising. This indicates that TODs not only foster the realization of social and environmental goals, but that they promote healthier life habits by enabling residents to be more active in their daily lives. The implementation of TODs seems to be a positive step on the journey towards a sustainable future.

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TABLE 1 Literature review

Type of variables	Expected relation on: Driving	Transit	Active mode	References
Socio-economic				Bhat 1997, Bhat and Sardesai, 2006; Schimek, 1996; Shen, 2000.
Sex (Female)	-	+		Curtis & Headicar, 1997; Nurdden et al. 2007.
Age	+	-	-	Hensher, 2007; Mercado et al., 2010; Scheiner & Holz-Rau, 2013.
Household size	+	-		Scheiner, 2010.
Education level	M	M	M	Carse et al., 2013; Schwanen et al., 2001; Tacken, 2008; de Witte et al. 2008.
Income	+	-		Chatman, 2006; Mercado et al., 2012; Moniruzzaman & Paez, 2012; Schimek, 1996.
Number of vehicle in household	+	-		Scheiner & Holz-Rau, 2013, chatman, 2013.
Constraints (Children, busy agendas, trip chaining)	+			Eriksson et al. 2010; Strathman & Dueker 1996, Ye et al., 2007; Scheiner, 2010; Hensher and Reyes, 2000.
Driver's license	+	-		Chatman, 2006.
Built environment				
Mixed-use environment	-	+	+	Boer et al. 2007; Cervero & Gorham, 1995; Frank et al,. 2000; Kockelman, 1997; Hess et al. 1999; Srivasan & Ferrreira 1999; Saelens et al., 2003; Scheiner & Holz-Rau, 2013.
Origin density	-	+	+	Chen, 2008; Kitamura et al., 1997; Kockelman, 1997; Hess et al., 1999; Messenger & Ewing,1996; Ross & Dunning, 1997; Saelens et al., 2003; Scheiner & Holz-Rau, 2013; Strathman and Dueker, 1996.
Destination density	-	+	+	Cao, Mokhtarian, & Handy (2009), Chen, 2008; Frank et al., 2000; Messenger & Ewing 1996; Schimek, 1996.
Employment density	-	+	+	Buch & Hickman, 1999; Ewing 1997.
Pedestrian environment (Pedestrian connectivity, Ease of street crossing, Safe surroundings, etc.)			+	Cervero & Kockelman 1997. Chatman 2006; Greenwald and Boarnet, 2001; Greenwald, 2003.; Hess et al., 1999; Saelens et al., 2003.
Time, distance and accessibility				
Travel distance	+	-	-	Carse et al., 2013; Scheiner, 2010.
Travel time	+	-	-	Eriksson et al. 2010; Eluru et al., 2012; Nurudden et al., 2007;

				Limtanakool et al., 2006.
Employment & amenities accessibility			+	Kockelman, 1997; Krizek, 2003.
Transit access at origin & destination	-	+	+	Cervero, 1994; 2007; Cervero & Gorham, 1995; Chatman, 2006; Evans et al. 1997; Kitamura et al., 1997; Nurdden et al., 2007; Schneiner & Holz-Rau, 2013.
Number of transfer		-		Eluru, Chakour & El-Geneidy, 2012.
Initial waiting time		-		Scheiner & Holz-Rau, 2013; Elur et al., 2012.
Parking and Cost				Cervero, 1994; Cervero & Kockelman 1997; Kuzmyak et al. 2010; Marsden, 2006; Lari et al., 2014.
Parking availability	+	-	-	Chatman, 2006, 2013; Chung, 1997; Scheiner & Holz-Rau, 2013.
Parking cost	-	+	+	Chatman, 2001, 2006; Strathman and Dueker, 1996; Carse et al., 2013; Scheiner & Holz-Rau, 2013.
Cost of using a car	-	+	+	Eriksson, 2011
Discount or free transit pass	-	+		Lari, 2014; de Witte et al., 2008.
Commute satisfaction				Abou-zeid et al., 2012; Kingham et al. 2001.
Car satisfaction	+			
Transit satisfaction		+		
Active mode satisfaction			+	
Control variables				
Self-selection				
Pre-existing travel preferences	M	M	M	Boarnet & Sarmiento 1998, Chatman, 2006, 2009; Krizek, 2003; Manaugh & El-Geneidy, 2014; Cao et al. 2009.
Attitudinal				
Attitude towards different travel modes				Chatman, 2003.
Positive attitude-> transit		+		Vredin Johansson et al., 2006 (environmental prefererences).
Positive attitude->active mode			+	
Perceived difficulty to use transit		-		Eriksson et al. 2010.
Perception of reliability & flexibility		+		Abou-zeid et al., 2012; Vredin Johansson et al. 2006; Kingham et al., 2001; Bhat & Sardesai, 2006.

Note: "M" means that literature results are mixed.

TABLE 2 Descriptive statistics

Variables	Description	Obs	Mean	SD	Min	Max
Gender	DV: 1 "Female"; 0 "Male"	2406	0.49	0.50	0	1
Age	Continuous	2420	43.27	14.28	18	86
Years spent in a TOD	Continuous	2459	9.22	10.04	0	68
Children in the household	Discrete	2443	1.18	0.56	1	6
Household size*	Discrete	2447	2.44	1.56	1	20
Vehicle in the household	Discrete	2454	1.48	0.81	1	7
Employed	DV: 1 "Employed"; 0 "Unemployed"	2459	0.79	0.41	-	
University degree	DV: 1 "University degree"; 0 "otherwise"	2459	0.46	0.50	-	
Household income >$80,000*	DV: 1 "Annual gross income household >= $80,000"; 0 "otherwise"	2088	0.51	0.50	-	
Driver's license	DV: 1 "Driver's license"; 0 "otherwise"	2459	0.92	0.28	-	
Increased in number of vehicle*	DV: 1 "Number of vehicles in the household increased when I moved"; 0 "otherwise"	2459	0.20	0.40	-	
New homeowner*	DV: 1 "I became owner of my residence after moving"; 0 "otherwise"	2459	0.20	0.40	-	
Rent	DV: 1 "Household unit is rented"; 0 "otherwise"	2459	0.42	0.49	-	
Previously rented	DV: 1 "Previous household unit was rented"; 0 "otherwise"	2389	0.69	0.46	-	
Reduced transit fare*	DV: 1 "Access to a free or reduce transit fare"; 0 "otherwise"	2459	0.22	0.41	-	
Free parking at work*	DV: 1 "Access to free car parking at work or at school"; 0 "otherwise"	2459	0.27	0.44	-	
Current Walk Score	Discrete	2439	73.76	16.85	12	100
Previous Walk Score	Discrete	2366	66.78	26.12	0	100
Increased in Walk Score*	DV: 1 "Current Walk Score > Previous Walk Score"; 0 "otherwise"	2355	0.43	0.50	-	
Density (km^2)	Continuous	2032	4.44	2.21	0.09	14.12
Previous density (km^2)	Continuous	1951	4.47	5.25	0.00	38.70
Density variation	Continuous (Density - Previous density)	1916	-0.13	5.72	-36.50	7.55
Increased in density	DV: 1 "Density > Previous density"; 0 "otherwise"	2459	0.26	0.44	-	
Walking time to grocery (min)*	Continuous	2453	35,98	59.52	0.83	891.93
Nearest transit stop (min.)*	Continuous	3984	6.81	6.31	0.00	51.00
Walk more	DV: 1 "I would like to walk more than I currently do"; 0 "otherwise"	2459	0.70	0.46	-	
Transit more*	DV: 1 "I would like to take transit more than I currently do"; 0 "otherwise"	2459	0.30	0.46	-	
Drive more	DV: 1 "I would like to drive more than I currently do"; 0 "otherwise"	2459	0.15	0.36	-	
Comfort	DV: 1 "I feel comfortable using transit"; 0 "otherwise"	2459	0.82	0.39	-	

Privacy	DV: 1 "When planning a trip my personal privacy is imp."; 0 "otherwise"	2459	0.46	0.50	-
Price of fuel is imp.	DV: 1 "When planning a trip the price of fuel is imp."; 0 "otherwise"	2459	0.54	0.50	-
Environmental impact*	DV: 1 "When planning a trip the environmental impact of my chosen mode is imp."; 0 "otherwise"	2459	0.56	0.50	-
Enjoyment is imp.	DV: 1 "Overall enjoyment of the trip is imp."; 0 "otherwise"	2459	0.73	0.45	-
Health is imp.	DV: 1 "Long-term effect of my trips on my health is imp."; 0 "otherwise"	2459	0.62	0.48	-
Reason for moving 1*	DV: 1 "I needed less space"; 0 "otherwise"	2459	0.05	0.21	-
Reason for moving 2	DV: 1 "I wanted to be closer to my work"; 0 "otherwise"	2459	0.16	0.36	-
Reason for moving 3	DV: 1 "I wanted to be closer to my partner/spouse's work"; 0 "otherwise"	2459	0.06	0.24	-
Reason for moving 4*	DV: 1 "I couldn't afford my previous home any more"; 0 "otherwise"	2459	0.04	0.19	-
Reason for moving 5*	DV: 1 "I wanted to be closer to public transit"; 0 "otherwise"	2459	0.20	0.40	-
Reason for moving 6	DV: 1 "The cost of parking are lower"; 0 "otherwise"	2459	0.01	0.10	-
Reason for moving 7	DV: 1 "The cost of transport to work/school are lower"; 0 "otherwise"	2459	0.05	0.22	-
Chose neighborhood based on:					
Proximity to work/school	DV: 1 "Proximity to work/school"; 0 "otherwise"	2342	0.84	0.37	-
Proximity to public transit	DV: 1 "Proximity to public transit"; 0 "otherwise"	2389	0.83	0.37	-
Cost of travelling	DV: 1 "Cost of travelling'; "otherwise"	2318	0.70	0.46	-
Possibility of less driving	DV: 1 "Being in a location where I could drive less"; "otherwise"	2296	0.72	0.45	-
Neighborhood walkability*	DV: 1 "The walkability/bikeability of the neighborhood'; "otherwise"	2387	0.81	0.39	-
Proximity to schools	DV: 1 "The proximity to quality schools for my children"; "otherwise"	1373	0.70	0.46	-
Work*	DV: 1 "Trip to work "; 0 "otherwise"	2459	0.12	0.33	-
Gym or indoor recreation	DV: 1 "Trip to gym or indoor recreation"; 0 "otherwise"	2459	0.13	0.34	-
Service provider	DV: 1 "Trip to a service provider (bank, pharmacy, etc.)"; 0 "otherwise"	2459	0.19	0.39	-
Cafe, bar or restaurant	DV: 1 "Trip to cafe, bar or restaurant "; 0 "otherwise"	2459	0.19	0.39	-
Main shopping street or mall*	DV: 1 "Trip to the main shopping street or shopping mall"; 0 "otherwise"	2459	0.19	0.39	-
Entertainment	DV: 1 "Trip for entertainment purpose (theater,cinema, etc.)"; 0 "otherwise"	2459	0.18	0.38	-

Notes: * variables used in the model. Other variables were not kept because of insignificance.

a. Nearest transit stop is defined as the closest transit stop to the respondent's home on foot (walking time in minutes).

b. “DV” is an abbreviation for dummy variable.

1 **TABLE 3 Travel mode choice before and after moving to TOD, by trip's purpose (%)**

	Travel mode choice					
	Automobile		Public transit		Active mode	
Trip purpose	**Previous**	**Current**	**Previous**	**Current**	**Previous**	**Current**
Work	43.85	48.5	37.54	36.21	18.6	15.28
Gym or indoor recreation	40.73	39.51	9.12	5.17	50.15	55.32
Service provider	46.74	41.74	9.78	7.39	43.48	50.87
Café, bar or restaurant	47.39	43.48	9.35	8.91	43.26	47.61
Main shopping street or mall	56.10	56.32	16.49	16.06	27.41	27.62
Entertainment	56.79	49.32	18.55	18.55	24.66	32.13
Total (%)	49.29	46.73	15.86	14.56	34.85	38.71

2
3

TABLE 4 Previous travel mode used by type of switch and trip purpose (%)

Trip purpose	Previous travel mode	Switched to		
		More sustainable	The same	Less sustainable
Work	Automobile	31.06	68.94	0.00
	Public transit	14.16	53.10	32.74
	Active mode	0.00	25.00	75.00
	Total	18.94	54.82	26.25
Gym or indoor recreation	Automobile	37.31	62.69	0.00
	Public transit	60.00	26.67	13.33
	Active mode	0.00	70.91	29.09
	Total	20.67	63.53	15.81
Service provider	Automobile	38.14	61.86	0.00
	Public transit	57.78	26.67	15.56
	Active mode	0.00	67.00	33.00
	Total	23.48	60.65	15.87
Café, bar or restaurant	Automobile	37.16	62.84	0.00
	Public transit	30.23	44.19	25.58
	Active mode	0.00	67.34	32.66
	Total	20.43	63.04	16.52
Main shopping street or shopping mall	Automobile	23.28	76.72	0.00
	Public transit	16.88	55.84	27.27
	Active mode	0.00	56.25	43.75
	Total	15.85	67.67	16.49
Entertainment	Automobile	31.87	68.13	0.00
	Public transit	25.61	48.78	25.61
	Active mode	0.00	55.05	44.95
	Total	22.85	61.31	15.84
Total		**20.41**	**62.22**	**17.36**

TABLE 5 Results of the multilevel multinomial logistic regression on the probability of switching to a more or switching to a less sustainable mode of transportation

	More sustainable vs No switch				Less sustainable vs No switch			
			Confidence interval (95%)				Confidence interval (95%)	
Independent variable	**RRR**	**Z**	**Lower**	**Upper**	**RRR**	**Z**	**Lower**	**Upper**
Household income >$80,000	0.69	-1.33	-0.92	0.17	1.08	0.24	-0.57	0.73
Household size	0.74	-2.49 **	-0.54	-0.06	1.09	0.67	-0.17	0.34
Increased in number of vehicle	1.43	0.92	-0.40	1.11	2.96	2.95 ***	0.36	1.81
New homeowner	1.16	0.52	-0.42	0.72	2.15	2.26 **	0.10	1.43
Increase in Walk Score	1.99	2.54 **	0.16	1.22	0.24	-3.85 ***	-2.14	-0.69
Free parking at work	0.50	-2.16 **	-1.33	-0.06	3.73	3.30 ***	0.53	2.10
Reduced transit fare	1.71	1.66 *	-0.10	1.17	0.26	-3.65 ***	-2.07	-0.62
Environmental impact	2.45	3.07 ***	0.32	1.47	0.38	-2.82 ***	-1.63	-0.29
Neighborhood walkability	1.96	1.79 *	-0.06	1.41	0.51	-1.44	-1.60	0.25
Transit more	0.53	-2.05 **	-1.23	-0.03	1.08	0.21	-0.65	0.80
Reason for moving 1	4.37	2.65 ***	0.38	2.56	1.95	0.65	-1.37	2.71
Reason for moving 4	0.15	-2.21 **	-3.57	-0.22	2.01	0.87	-0.88	2.28
Reason for moving 5	2.39	2.73 ***	0.25	1.50	0.79	-0.62	-0.99	0.52
Walking time to grocery (min)	0.99	-2.77 ***	-0.02	0.00	1.00	0.66	0.00	0.01
Nearest transit stop (min)	0.92	-2.71 ***	-0.14	-0.02	1.04	1.33	-0.02	0.10
Shopping trip	0.37	-4.41 ***	-1.42	-0.55	1.59	1.81 *	-0.04	0.97
Working trip	1.19	0.72	-0.30	0.65	2.87	3.84 ***	0.52	1.59
Previous mode: automobile	12.38	8.93 ***	1.96	3.07	0.00	-0.01	-9391.35	9340.21
Constant	0.04	-3.11 ***	-4.22	-2.00	0.49	-0.69	-1.88	0.48
N=1941								
LR chi^2 (42)=1045.14 Pseudo R^2=0.30								
var(M1[id])	2.93	0.59	1.98	4.36				
var(M2[id])	3.06	0.75	1.89	4.96				
cov(M2[id],M1[id])	-0.32	-0.64	-1.29	0.66				

Note: No switch is the reference (Base outcome) of the model, and it means that the person uses the same travel mode after relocation.

*** p<.01; **p<.05; *p<.10.

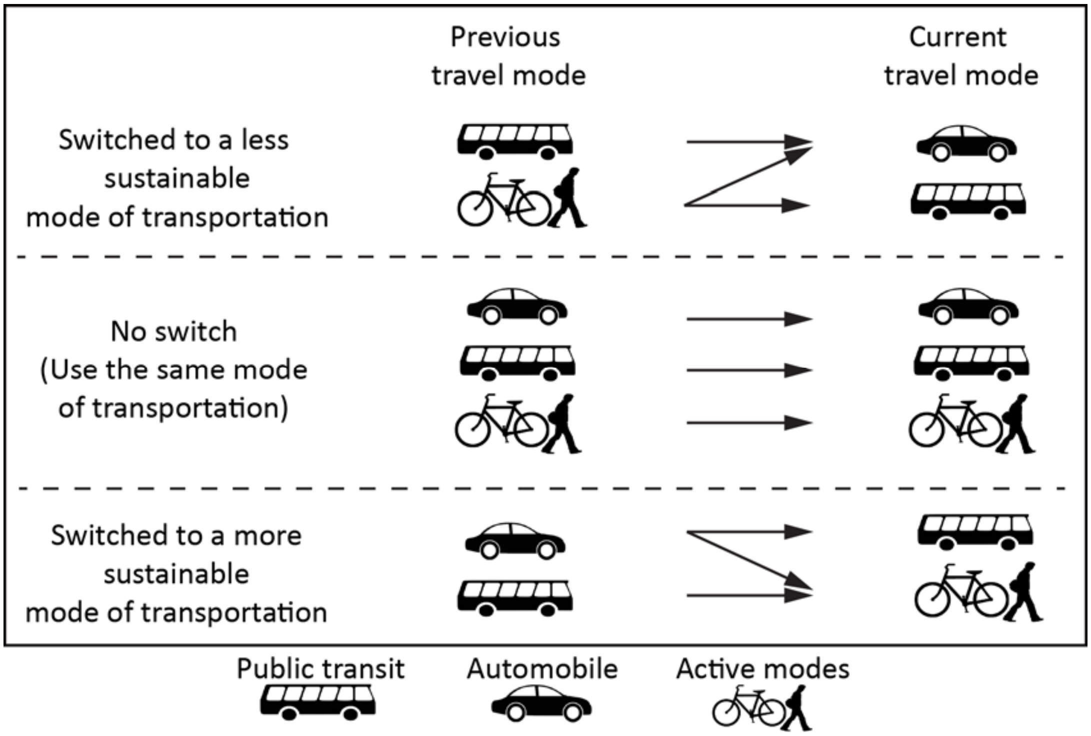

FIGURE 1 Classification of the travel mode changes made by newcomers to TODs