Built Environment versus Personal Traits: an Application of Integrated Choice and Latent Variable Model (ICLV) in Understanding Modal Choice in Rome, Italy

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Abstract

In spite of numerous applications of **Integrated Choice and Latent Variable** (ICLV) modelling in the field of transportation engineering, there is no published work applying it in studies of the effect of built environment on modal choice. This study uses an ICLV model to investigate the relative importance of built environment versus personal traits. It designs a quasi-experiment to elicit a better understanding of the causal effects of several urban form characteristics on modal choice. Findings suggest that built form can compete with the magnitude of the influence of personal traits, if all the urban form factors of design, local street network integration, population density and diversity be incorporated together. Otherwise, there would either be a trade-off in choosing what trip purpose we aim to focus on or there would be a very slight, if any, change in overall travel behavior.

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1. Introduction

Over the past several decades, the adverse effects of increasing use of private vehicles have motivated a considerable number of studies that investigate the factors involved in travel mode choices. While transportation engineers tend to focus on the effects of travel cost, time and other alternative specific attributes (e.g. Hess et al., 2005; Chorus, 2007), in urban planning many studies attribute growing motorization to patterns of urbanization (see Ewing and Cervero (2010), for a review). Researchers in both fields have emphasized the importance of accounting for taste heterogeneity (e.g. Handy et al., 2005; Cervero, 2007; Cao et al., 2009; Gaker et al., 2011).

The integrated choice and latent variable model (ICLV) is claimed to be one of the most useful models for investigating the effects of unobservable variables, although its contribution in terms of statistical benefits has remained unclear (see Vij and Walker, 2012). However, to the authors' knowledge, in spite of numerous applications of this model in the field of transportation engineering (e.g. Johansson, 2005; Theis, 2011; Johansen, 2013), there is no published work applying it in studies of the effect of built environment on modal choice. Put differently, attitudes have been included in such studies as other observable variables in traditional multinomial logit models, which may lead to spurious results as they do not account for the likely effects of the observable variables (e.g. sociodemographic factors) on the unobservable variables (attitudes and preferences). Furthermore, in spite of the development of an extensive literature documenting relationships between travel behavior and patterns of urbanization, considerable disagreement exists over the likely magnitude of the impacts of increased density, diversity, street connectivity, and design variables (Frank, 2000; Ewing and Cervero, 2010; Schneider, 2011) on travel behavior. Critics of these studies question the ways in which urban form is measured. Ewing and Cervero (2010) argue that design (e.g., street layout, parcelization) has an ambiguous relationship to travel behavior and that any effect may be an interactive effect with other factors such as density and diversity.

Space syntax (Hillier and Hanson 1984) is a set of methods developed to allow designers to analyze the likely impacts of their designs, using maps and graphs to analyze connectivity, syntactical accessibility (i.e. street network integration), and flows (e.g. Long, 2007). While its advocates argue that space syntax measures correlate with movement patterns which in turn affect land use patterns (e.g. Hillier and Penn, 2004), others believe that in fact it is land use that affects movement patterns (e.g. Ratti, 2004).

This debate has important implications for urban planners and designers. For example, although some studies have shown a correlation between syntactical accessibility and a propensity for walking (e.g. Baran et al., 2008), a spatially well integrated street network may not change travel behavior, if the land use patterns and density of uses do not encourage walking. The opposite is also possible.

This paper argues that most studies of the effects of built environment on modal choice have conducted correlational research rather than quasi-experiments which have more control than a typical correlational study. The contribution of this study is threefold. First, it uses an ICLV model to investigate the relative importance of built environment versus personal traits. Second, it designs a quasi-experiment which aims to understand the relative importance of different urban form factors and examine whether the influence of each is autonomous or an interactive one affected by multiple factors for work versus non-work trips. Finally, this is the first study to investigate the possible effect of local street network integration using "angular analysis" in the space syntax methodology.

The paper continues with description of the research approach. Section 3 presents data analysis stages. Section 4 concludes the paper with discussions on contribution of this study to the existing academic and policy debates, and future research directions.

2. Research Approach

This study seeks to understand whether the urban form factors of diversity, population density, design and local street network integration have a causal effect on modal choice through a quasi-experiment that puts together and analyzes the effect size of different urban and non-urban form factors. In a true experiment, the independent variable (i.e. the built environment) must be manipulated by the investigator in order to demonstrate that it has a causal effect upon the dependent variable (modal choice). Extraneous variables must be neutralized or subject to experimental control (Kinnear and Gray, 2006). Furthermore, participants should be assigned randomly to treatment and control groups and behavior be measured for both groups before and after the treatment of interest. Since it is not possible to design a true experiment for the research in the field of urban planning (e.g. it is not possible to assign people randomly to live in certain neighborhood types), an approach that is close to true experiment has been designed to allow for a causal comparative study. The built environment is represented by 9 categories of streets including one as the control group, in which all the studied urban form factors are low, and the other 8 categories as treatment groups each representing a different mixture of the abovementioned 4 urban form factors.

2.1 Survey Site Selection

Local street network integration in a low metric radius was measured through a syntactical analysis of the street network of Rome using space syntax methodology in Depthmap10 software. This integration value is an indicator of how easily one can reach all the other streets surrounding the street segment of interest (trip origin) and vice versa (ease of access to that specific street segment, as destination). The ease of access is measured based on the number of turns one should take (known as topological distance) and the angles between streets' axes (geometrical distance) in a given metric radius. This study conducted an angular analysis with the topological distance of 3 (reaching the surrounding streets with a maximum of 3 turns) within a 1 km radius, to capture the most and the least locally integrated areas of the city and examine whether this integration value affects more propensity for active transportation.

40 areas with different local integration values were randomly selected and the integration values of their central streets were normalized to categorize them under two categories of low and high integration. A circle with the radius of 1 km was defined around the selected segments in ArcGIS to analyze other characteristics. The latest population census from ISTAT (National Institute of Statistics in Italy) was used and the average population density was calculated in ArcGIS for each area. Population density was normalized as well to categorize the areas into categories of low and high population density. The selected areas were, then, observed for their diversity and design characteristics. Mono-functional areas encompassing only residential buildings with very few retails available (more than 80% residential use) were considered low-diversity. Conversely, the areas that had a mix of functions, including residential, retails and other commercial uses, and services, were considered high-diversity. For design characteristics, sidewalk provision, standard sidewalk width, street lighting, planted strips, flat terrain, eyes on the street (windows and doors opening onto street), and pedestrian crossings were considered. If an area had all the seven characteristics it went under the category of high design quality and if it had only 3 of those characteristics (flat terrain, eye on street and street lighting) it was considered an area of low design quality.

Finally, 17 areas with different degrees of the abovementioned characteristics were selected and categorized under 9 different types of built environment. All the selected street segments have easy access to bus stations. When under a built environmental category, streets with and without access to Metro station were found that category was divided into two sub categories. In order to increase randomization, when possible, more than one street is selected under each category of built environment (see table 1). Therefore, a street panel parameter was included in the model to account for the effect of any other street specific characteristics that may have not been measured.

Table 1. Characteristics of the nine street types

Street type	**Local integration**	**Population density**	**Diversity**	**Design quality**	**Subway station availability**	**Street name**
1	High	High	High	High	Available	1)Viale Angelico 2)Viale XXI Aprile 3)Appia Nuova 4)Viale Libia
2	High	High	High	High	Not available	5)Viale Guglielmo Marconi
3	Low	High	High	High	Available	6)Via Tuscolana & Lucio Sestio 7)Via Tiburtina
4	Low	High	High	High	Not available	8)Via Prenestina 9)Viale Val Padana 10)Viale Antonio Ciamarra
5	High	Low	Low	Low	Not available	11)Via Monte delle Capre 12)Via Casilina and Rocca Cencia
6	Low	Low	Low	Low	Not available	13)Via dei Pioppi and Via degli Olmi 14)Via Siculiana
7	Low	Low	Low	High	Not available	15) Via Biagio Petrocelli
8	High	High	High	Low	Not available	16)Via del Pigneto and Via Gabrino Fondulo
9	High	Low	High	High	Not available	17)Viale Trastevere

2.2 Survey Instrument and Procedure

Besides built environment and personal traits, numerous alternative specific attributes, travel factors, and socio-demographic characteristics have been included in this study as extraneous factors and were measured based on responses to a questionnaire. It included basic background information, 42 likert-scale statements asking opinions about travel, 30 likert-scale statements asking opinions about respondents' preference for a number of neighborhood characteristics, and respondents' mode choice in 2 most recent days (one day for getting to work/school and one day for other trip purposes). Respondents were asked to report the modes they used between any stops before arriving at their destination, the time they left home and arrived at their destination, and any out of pocket cost of the trip. The survey was conducted between May 1st and July 31st 2013. 524 adults (≥18) living in the selected street segments in Rome participated; 279 males and 245 females. The survey was distributed in two ways: 1) when possible it was delivered in person 2) The lead researcher or the assistants approached people in public places, explained about the research objective and asked whether they lived in the study area and were interested to participate in the survey. In both cases participants were asked to fill the questionnaire immediately. Each survey took 15–25 minutes to complete.

3. Data Analysis

3.1 Personal Traits within the Sample Population

Factor analysis was conducted separately for statements measuring attitudes towards travel, and statements measuring preferences for certain neighborhood characteristics in R package. Varimax rotation was used to calculate the loadings of each Statement onto specific factors. 15 latent factors including cost sensitivity, pro-transit, childcare options consideration, pro-driving, susceptibility to peer pressure (regarding the value that they attribute to walking, taking transit or driving), car safety and flexibility consideration, pro-biking, anti-travel, environmental accountability, pro-walking, waiting time sensitivity, distance sensitivity, and willing to drive only were identified for attitudes. Eight latent factors including preference for walkability, diversity in building styles and socializing opportunities, accessibility and safety of neighborhood streets, social interaction, spaciousness and attractiveness, access to services and amenities, safety and security, and access to local shops were identified for preferences for certain neighborhood characteristics.

3.2 Integrated Choice and Latent Variable Modelling (ICLV)

ICLV models can give us interesting new insights not only about the effect of latent factors but also about the way socio-demographic factors affect mode choice through their influence on latent factors (the so called personal traits). This is especially useful in the context of forecasting and can be informative to policy makers as it allows for prediction of different personality traits for different segments of individuals, and, hence, the distribution of personality traits over the whole population (Johansen, 2013). Put differently, the explicit incorporation of psychometric data and latent constructs within existing representations of the decision-making process, frees the analyst from restrictions arising out of simplifying assumptions made by traditional models (Vij and Walker, 2012). In the ICLV model, two structural equations are estimated simultaneously; one explaining the latent variables with socio-demographic characteristics where the indicators are used as manifestations of the latent variable, and the other one explaining the utility of each alternative with observable and latent variables (Theis, 2011).

In this study, a number of ICLV models were estimated for work and non-work trips, using Python Biogeme by Bierlaire (2003). Figs. 1 through 4 present the results of estimating the final models. In this paper, we only discuss the effects of built environment and personal traits. However, it is emphasized that the variable of trip purpose for non-work trips, did not show significance and was therefore excluded from the final model. Therefore, the results presented for non-work trips pertain to all non-work trip purposes. The street panel parameter was insignificant as well for all alternatives suggesting that there are no significant unmeasured street specific characteristics that would affect mode choice in this study.

Results suggest that certain attitudes (pro-transit, pro-biking, susceptibility to peer pressure, and environmental accountability), and preferences (preference for walkability, spaciousness and attractiveness, and safety and security of the neighborhood) do play a significant role in explaining travel patterns. Nevertheless, neighborhood's physical structure appears to have an autonomous influence and five types of streets (Types 1,2,3,4, and 9) showed significant positive effect on walking and transit use.

The personal traits affecting mode choice for work versus non-work trips were completely different. For work trips, being pro-transit and susceptibility to peer pressure (the value that neighbors attribute to sustainable travel) showed a significant positive effect on both walking and transit use while having environmental accountability and preference for walkable neighborhoods showed significant positive effect only on walking. Instead, for non-work trips, being pro-biking showed to have a significant

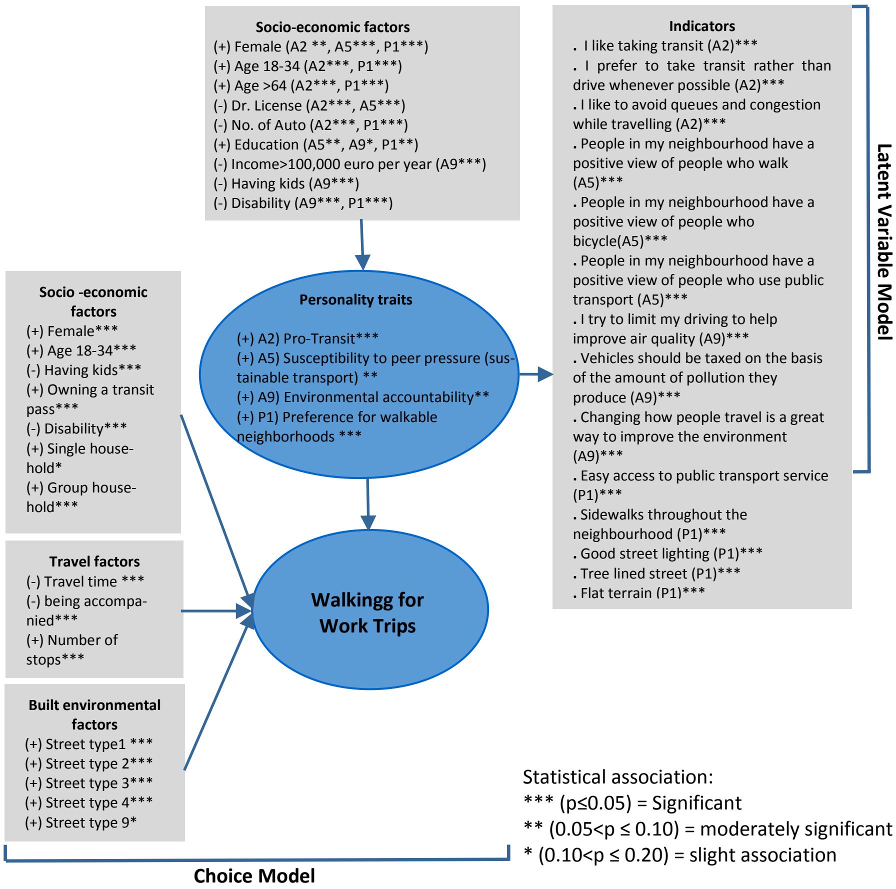

Fig. 1. Factors associated with walking for work trips

positive effect on both walking and transit use while preference for safe and secure neighborhoods showed a positive effect, and preference for spacious and attractive neighborhoods showed a negative effect on walking.

The results of the ICLV model also allowed for a better understanding of the effects of socio-demographic factors. It was found that although some of these factors do not show a direct significant effect on mode choice, they affect it indirectly through their influence on personal traits. For example, while being older than 64 doesn't show a direct positive effect on sustainable mode choice for work trips, it seems that this demographic factor has a significant indirect effect through its influence on pro-transit attitude. Same goes for the influence of education on environmental

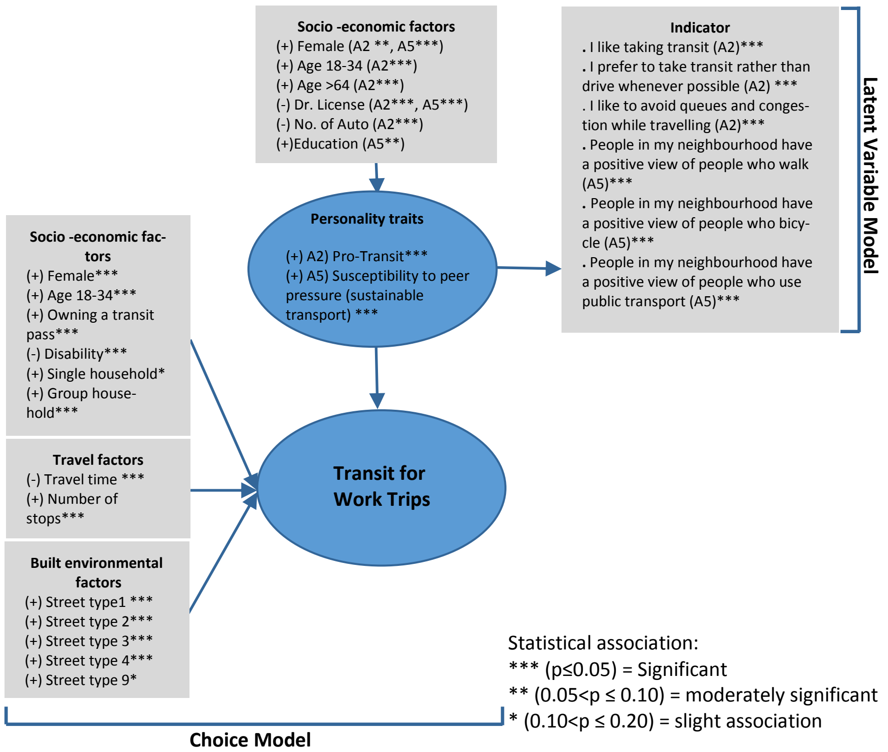

Fig. 2. Factors associated with transit use for work trips

accountability and susceptibility to peer pressure.

Although 5 types of streets showed significant positive effects on mode choice, their parameter estimates and significance values differed and comparing their values or the ratio of each of the types in which one or more of the urban form factors are lacking to the type where all the urban form factors are high provides an insight about the way those different urban form factors affect walking and transit use for work versus non-work trips. Therefore, the street types that were comparable (i.e. differed only in one characteristic) were compared to one another (types 1 and 2, 3 and 4, 2 and 4, 2 and 9, and 1 and 3).

According to the results, for all trip purposes, when all the 4 studied urban form factors are high (Types 1 and 2) we notice the highest probability of sustainable mode choice. Moreover, subway station availability showed to increase walking and transit use for all trip purposes although its effect seems to be higher for work trips (type1>type2, and type3>type4).

Although lack of population density (type9) and lack of local integration

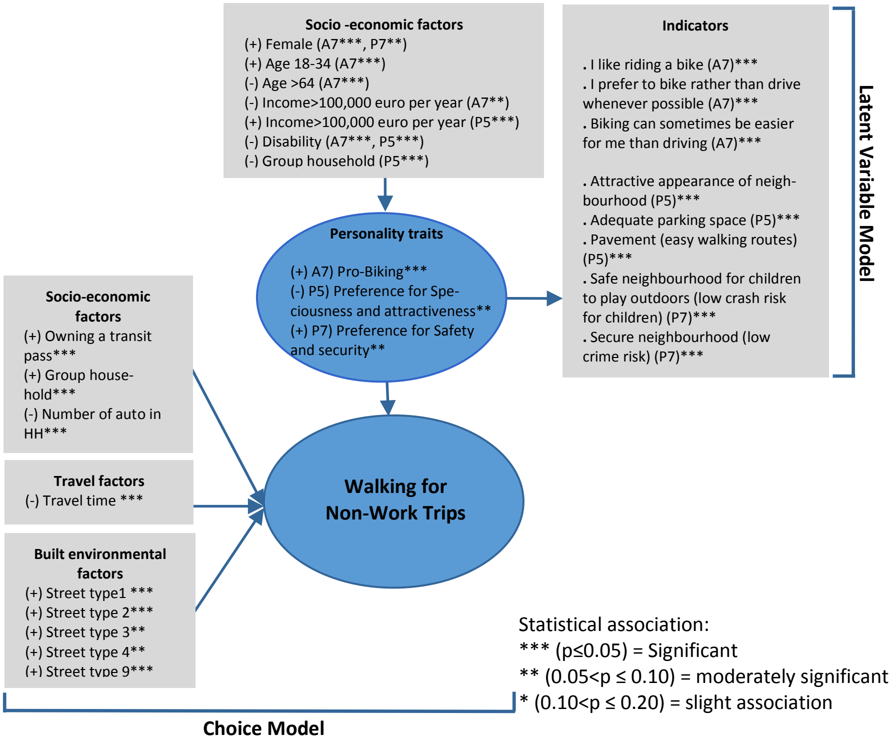

Fig. 3. Factors associated with walking for non-work trips

(type4) both decrease walking and transit use (compared to type 2 where everything is high) for all trip purposes, lack of population density has a more negative effect than lack of local integration for work trips. This effect is vice versa for non-work trips where lower population density seems to cause less decrease in walking and transit use than lower local street network integration. This contrast in the effect of local street network integration on work versus non-work trips could be due to the increased ease of access to all the other streets of the neighborhood that high local integration brings about which can ease both walking and driving. For work trips, in which time limitations are prevailing, a highly integrated neighborhood with low population density means easier use of car (less overall travel time due to less local congestion and well-connected streets) while a highly populated area with low local integration imposes some difficulties for car use. For non-work trips, on the other hand, in which comfort and enjoyment prevails, all else equal, a well-integrated area with low population density is more appealing for walking and transit use. However, in

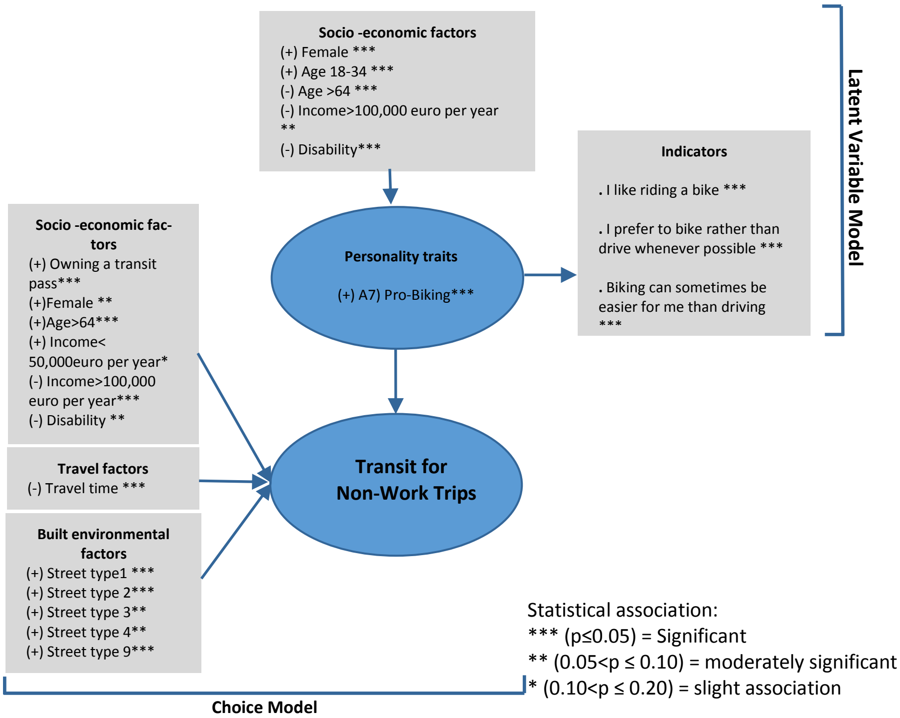

Fig. 4. Factors associated with transit use for non-work trips

street type 2 where all of the urban form factors are high including population density and local street network integration, population density compensates for the effect of local integration for work trips as more people in the neighborhood leads to more cars in the street, more local congestion, and more overall travel time. Likewise, high local integration which has a more positive effect for non-work trips compensates for the negative effects of high population density.

Furthermore, for both trip purposes lack of design quality decreases the possibility of walking and transit use dramatically. This type (type 8) does not even show a significant effect on sustainable mode choice although other characteristics are high. Although types 5 and 7 did not show significant effect on mode choice and were therefore excluded from the final model comparing their coefficient values before being removed from the model confirmed the aforementioned conclusions. Type 7 in which only design quality was high still shows a positive effect on sustainable mode choice for all trip purposes while type 5 in which only local integration is high shows a negative effect on sustainable mode choice for work trips and a very small positive effect for non-work trips.

Furthermore, a comparison of the magnitude of the influence of personal traits, socio-demographic factors and different street types revealed that the magnitude of the effect of urban form is comparable to that of personal traits and socio-demographic factors when all the studied urban form factors are combined. However, this effect diminishes when one or more of these built-form characteristics are missing.

4. Discussion and Conclusion

This study contributes to the analytical and normative, as well as the academic and policy debates. While the results of this study are consistent with the mainstream literature on the influence of attitudinal factors on mode choice (e.g. Johansson et al., 2005; Cao et al., 2009), findings do not comply with the studies (e.g. Cervero and Kockelman, 1997; Xing et al., 2008) suggesting that the influence of personal traits and socio-demographic factors are higher than built-form characteristics. Put differently, this study suggests that the built form can significantly cause sustainable mode choice for all trip purposes and compete with the magnitude of the influence of personal traits, if all the urban form factors of design, local integration, population density and diversity be incorporated together. Otherwise, there would either be a tradeoff in choosing what trip purpose we aim to focus on or there would be a very slight, if any, change in overall travel behavior. Improving design quality is effective for all trip purposes and the magnitude of its effect is higher than that of population density and local integration. On the other hand, population density is more effective for work trips while local integration is more effective for non-work trips. Furthermore, findings suggest that increasing separate characteristics may either have a very slight, if any, effect (e.g. high design quality) or bring about an adverse effect (e.g. High local integration) on sustainable mode choice. This suggests that any one-sided intervention in cities with the goal of reducing private car usage without considering the multitude of urban form characteristics that affect mode choice could lead to unwanted outcomes and intensified urban life problems. Conversely, a comprehensive spatial analysis of the city to locate the areas which have the potential to respond positively to proposed interventions could bring about desired results.

One contribution of this study to the academic debates is the effect of local street network integration in a low metric radius of 1 km on modal choice in addition to other characteristics of the built environment (density, diversity and design). However, the results show that this characteristic can increase both pedestrian and car movements. Consequently, while it is emphasized that an incautious use of space syntax methodology could lead to misinterpretations, we argue that it can be a useful tool for spatial analysis of the street network of the city and when combined with the analysis of land use and density, it can help in spatial planning and preparation of development plans by finding areas of the city that can accommodate interventions or new developments which encourage the use of more sustainable means of transportation and do not oblige or ease the use of private vehicles. The findings can also contribute to the debates about characteristics of transit oriented development centers (TOD) by offering some insights about how to determine the best location for subway stations. This is of particular use in Rome as it represents a very controversial issue in the planning debates, and seems to be rather underestimated in recent years' urban development.

Furthermore, since budget restrictions do not allow to improve the qualities of all neighborhoods of the city in a short period of time, the proposed spatial analysis performed in this study can be used for giving priority to improving the physical structure of the areas of the city that already have some of the qualities that encourage sustainable modes of transport. For instance, it is more cost effective to improve design quality of the areas which already have well integrated street network and mixed land use or to allocate subway station to areas which already have characteristics that encourage transit use but lack of subway availability reduces their usage (e.g. Types 2 and 4). Likewise, priority for new development should be given to the areas of the city which have an already well integrated street network.

The use of ICLV modelling in this study helped in increasing the methodological robustness and understanding the effects of psycho-sociological factors on mode choice. As Vij and Walker (2012) put it, one should exploit the additional parameters identified by the ICLV model which provide valuable information that cannot be captured from the reduced form multinomial logit models (Vij and Walker, 2012). A number of personal traits showed to have significant positive effect on mode choice in this study. While some of them are not easy to change, some lessons can be learnt for policy making.

Although biking was not a common choice in Rome and, therefore, was excluded from the model, the positive effect of preference for biking on walking and transit use for non-work trips can be explained as higher probability of sustainable mode choice for people who prefer active means of transportation. This also reveals some underlying relationships between some transportation modes meaning that people with preferences for certain modes may replace their preferred mode with another one, which may offer similar benefits, when that preferred mode is not available or restrictions of any kind are imposed. Therefore, the effect of biking preference emphasizes on the need for providing biking infrastructure and facilities in the city to facilitate biking which could increase the use of more active sustainable transportation in the city.

The finding from the structural component of the latent variable model can also be employed for policy analysis. For instance, the results of this study found that education has a positive effect on both environmental accountability and susceptibility to peer pressure, which eventually affect sustainable mode choice. Policy makers can use this information in different ways. This can include providing feedback to highly educated households regarding the value that their neighboring households attribute to the use of sustainable modes of transportation to increase the effect of this latent factor by increasing the number of people who are aware of their neighbors' values, or/and targeting less educated households and disseminating knowledge about the personal and environmental benefits of sustainable transportation modes to reduce the gap in environmental accountability resulting from the difference in the level of education. However as Vij and Walker (2012) mention, it is usually left to the analysts to make whatever assumptions about the effects such strategies would have and one must be thoughtful when making such assumptions.

Several additional avenues for further research can be identified. First, while the significance of the effect of a number of neighborhood preferences reveal the underlying effect of residential self selection and the importance of including such factors in choice models, in order to come up with more useful results about the effect of preferences for such neighborhood characteristics on modal choice, these variables should be interacted with the street type variable. Due to sample size restrictions such interactions have not been included in the ICLV model. Future studies with larger sample size could enter such interactions in the model. This will not only provide more reliable conclusions regarding the influence of self selection but also interesting insights on how certain opportunities offered or restrictions imposed by the physical structure of the city affect the mode choice of people with certain attitudes and preferences. Second, the separable effect of diversity could not be measured in this study as the spatial analysis of Rome revealed that this factor is usually combined with other factors of population density and local integration and could not be easily separated. Future research is needed to investigate the magnitude of the influence of diversity on modal choice through other experimental approaches or conducting the same analysis in other contexts. Finally, in this study, the effect of different design factors affecting modal choice was measured collectively. Further research using the same quasi-experimental approach could likely measure the influence of each design factor separately while other urban form factors are kept fixed.

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