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Participatory design in transit-oriented development uncovers social benefits

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Blanca Fernandez Milan[1,2,*], Felix Creutzig[1,2]

Abstract

Transit-oriented development (TOD) tackles multiple challenges simultaneously and fosters sustainable urban development. Low-carbon intensity transport modes help mitigating climate change, enhance the quality of local ecosystems and offer monetary savings. While less well studied, TOD also positively affects citizen's social interactions. The social sustainability that can be drawn from TOD interventions may multiply when designed through participatory planning processes. To investigate this hypothesis, we evaluate TOD and participatory intervention for Medellin (Colombia). We find that designing TOD together with participatory measures results not only in the decrease of motorized transport modes, but also in positive changes in socioeconomic variables, people´s perception of public interventions and in social capital especially of disadvantaged groups. Making citizens feeling part of the projects that shape their communities fosters transparency, trust, social inclusion, collective action and social networks. Participatory measures can catalyse urban sustainability.

Keywords: Transit-oriented development, social capita, participatory planning, urban upgrading.

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1. Introduction

Motivated by climate change and urban sustainability challenges, municipalities show an increasing interest in transit-oriented development (TOD) because it provides economic, social, and environmental benefits (Belzer and Autler 2002; Bongardt, Breithaupt, and Creutzig 2010; Felix Creutzig and He 2009; Felix Creutzig, Mühlhoff, and Römer 2012; Curtis, Renne, and Bertolini 2009; Newman and Kenworthy 1999; Renne 2008). Low-carbon intensity transport modes bring economic benefits in addition to the reduction of GHG emissions and other local air pollutants (Belzer and Autler 2002; Curtis, Renne, and Bertolini 2009; Nahlik and Chester 2014; Newman and Kenworthy 1999; Renne 2008; Felix Creutzig, Mühlhoff, and Römer 2012; Rahul and Verma 2013; Vickerman 2008). First, they generate savings to the entire system because they reduce congestion and transport related accidents (Bongardt, Breithaupt, and Creutzig 2010; Nahlik and Chester 2014; Newman and Kenworthy 1999; Rahul and Verma 2013; Vickerman 2008). Second, cities that reduce their motorized vehicles reduce expenditures on passenger and goods transportation (Belzer and Autler 2002; Newman and Kenworthy 1999). The use of public transit to the detriment of fossil fuelled vehicles also decreases household transport expenses, and together with mixed land use they enhance the quality of ecosystems and increase location values (Dubé et al. 2011; Nahlik and Chester 2014; Hasibuan et al. 2014; Nahlik and Chester 2014; Rahul and Verma 2013). TOD projects also attract additional investment, create jobs, and expand the catchment urban area, in turn leading to enhanced competitiveness at the regional and other levels (Knowles 2012). While less well studied, TOD also positively affects citizen's social interactions. But these outcomes seem to depend on how TOD interventions are designed and implemented (Glaeser and Gottlieb 2006; Dempsey, Brown, and Bramley 2012).

We use the case of Medellin (Colombia) to evaluate the social benefits of participatory TOD. Medellin has been widely used as a benchmark for its transit development in general and its participatory urban planning in marginalized areas in particular (Blanco and Kobayashi 2009; P. Brand 2010; Echeverri and Orsini 2011; Fukuyama and Colby 2011; Hylton 2007; J. Dávila 2014). Empirical evidence exist on the effects of its interventions on the reduction of violence and transport emissions (Cerda et al. 2012; J. Dávila 2012a), but lacks in systematic comparison on TOD modal shifts, on life quality in general and on social capita in particular. Our methods – based on data from the annual citizen survey - allow us to evaluate citizen´s changes on socioeconomic variables, their perception of public interventions, and their social capita for two comparison groups according to their changes in their use of TOD modes. Interestingly, positive changes in TOD modes coincide with the target population the participative TOD interventions wanted to address-. The structure of the paper is as follows: Section 2 reviews the literature on TOD and social capita, Section 3 introduces the case of Medellin; Section 4 explains the methods and data on which our research relies. Section 5 reports the main results, discussed in Section 6 and focusing on policy recommendations drawn by the case presented here. Section 7 concludes the paper.

2. TOD and social capital

Until now, empirical evidence has focused on the relationship between specific built environment characteristics of TOD areas (e.g. density, planned mixed land uses, walkability and street design) and social capital (one aspect of social sustainability). Social capital comprises all institutions, relationships, and customs that shape the quality and quantity of social interactions in a community (The World Bank 2011) (Figure 1). Findings suggest that the built environment influences social capital, but the empirical relationship remains unclear. For example, although TOD fosters dense development, denser neighbourhoods do not always provide higher social capital (Glaeser and Gottlieb 2006; Dempsey, Brown, and Bramley 2012). Mixed land uses, another intrinsic characteristic of TOD, also shows inconsistent outcomes (Leyden 2003; Lund 2003). Public transport accessibility levels typically fosters social inclusion, but its relationship with other social capital dimensions is still unknown (Janet Stanley and Lucas 2008; Janet Stanley and Vella-Brodrick 2009; Janet Stanley et al. 2010; Currie and Stanley 2008; John Stanley, Stanley, and Hensher 2012). What is clear is that walkable neighbourhoods perform better in terms of overall social sustainability. Specifically, pedestrian-oriented neighbourhoods foster a sense of community (Lund 2002; Leyden 2003; Du Toit et al. 2007), trust, political participation, and social engagement (Leyden 2003; Wood, Giles-Corti, and Bulsara 2012; Mason 2010). We identified only on case study – of Brisbane, Australia - comparing TOD and non-TOD areas. Results show that individuals living in TOD areas have a significantly higher level of trust and reciprocity and connexion with neighbourhood compared to non-TOD areas, which indicates that specific built environment characteristics of TOD areas may foster the development of social capital (Kamruzzaman et al. 2014). Still, the relationship between the design of TOD, the built environments and other aspects of social capital (i.e. participation in networks, civic engagement, the existence of pooled community resources and social norms) remains understudied.

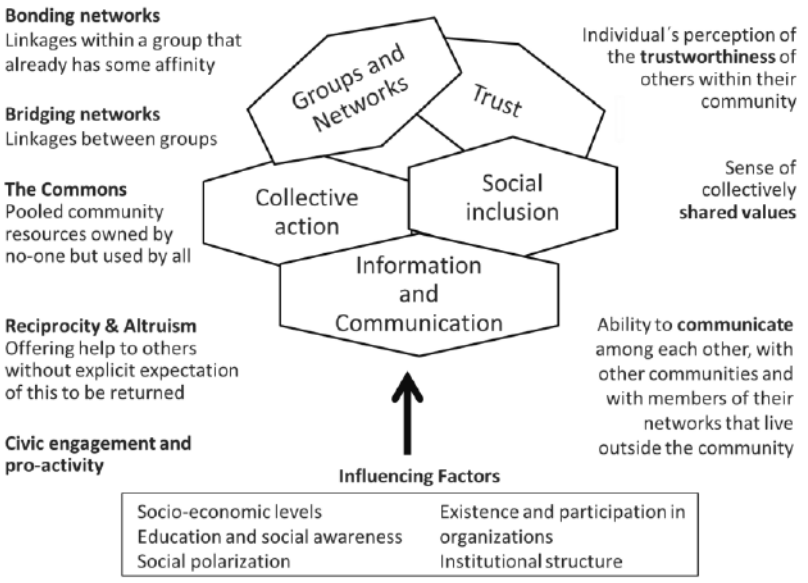

Figure 1 Social Capital: dimensions and influencing factors

TOD projects aim not only at reducing transport emissions, but also want to create public spaces and transform pre-existing ones, thus impacting communities beyond infrastructural changes. Public spaces are fundamental for the enhancement of social capital; they foster an atmosphere of trust and cooperation and develop links and mutual understanding among citizens and with government institutions. They also constitute a fundamental scenario for political and social engagement (Chen, Acey, and Lara 2015; Chen, Acey, and Lara 2014; Leyden 2003; The World Bank 2011). But the ways and extent to which TOD could influence communities' social sustainability have not been fully realized. Some projects have mixed goals that hamper adequate prioritization of social and cultural preferences (i.e. fostering economic growth, building a location brand or satisfying political interests) (Baumann and White 2012; Cervero, Ferell, and Murphy 2002; Dorsey and Mulder 2013; Boarnet and Compin 1999; Turner 2012). Traditionally narrow priorities based on utility-maximising rational and physical and functional requirements present poor awareness of the nexus between TOD and place making (Ndebele and Ogra 2014; Baumann and White 2012; Belzer and Autler 2002; Chiu, Huang, and Ma 2011; Winston and Maheshri 2007) and little integration of environmental values (Soria-Lara, Bertolini, and te Brömmelstroet 2015) and social considerations such as travel patterns (Bailey, Grossardt, and Pride-Wells 2007; De Vos, Van Acker, and Witlox 2014)). Intransigence of the target community on changes in lifestyles may also lead to unintended consequences. For example, the introduction of measures to avoid car usage (i.e. inner-city parking fees) may result in new suburban driving patterns, protests, and induced technological innovations that hamper social changes and, ultimately, sustainable development (Vallance, Perkins, and Dixon 2011; Clark 2005).

The design of appropriate interventions that take the social context into account increases the overall sustainability outcomes of TOD interventions. Specific to social capital, public participation in decision-making processes is commonly identified as a key factor of success (Bowling and Stafford 2007; Grootaert and Bastelaer 2001; Grootaert 1998; Kamruzzaman et al. 2014; Masoud, Rastbin, and Ardahaey 2011; Onyx and Bullen 2000; Roche 2004; The World Bank 2011). From the urban planner perspective, if wider sustainability objectives are to be achieved, transit infrastructure investment would benefit from parallel investments in housing, schools, the environment and public space (Peter Brand and Dávila 2011). These could generate synergies as the enhancement of social capital contributes to the development of sustainable development principles in the communities –e.g. fosters social equity and the preservation of natural ecosystems, among others- (Chen, Acey, and Lara 2015; Grootaert 1998; Grootaert and Bastelaer 2001; Putnam 1993; The World Bank 2011; Vallance, Perkins, and Dixon 2011). In the case of TOD project designs, participative interventions may foster eco-friendly behaviours related to urban mobility and shift social norms and perceptions related to active transport and lifestyles preferences (e.g. car dependency and preference to live in low-density suburban areas).

3. Medellin: Connecting TOD and place making

The construction of the mass transit system Metrocable and the works around stations through the participatory urban upgrading projects (Proyectos Urbanos Integrales, PUIs) transformed the public spaces in Medellin (P. Brand and Dávila 2011). Since mid-2000s, the development plans defined the territory as scenario targeting of public policies. They operate under the following principles: a) enhancing the natural environment; b) urban mobility; c) public space and housing conditions; d) and security and coexistence (Alcaldía de Medellin 2015; Alcaldía de Medellín 2004; Alcaldía de Medellín 2008; Alcaldía de Medellín 2012; P. Brand 2010).

The government first developed an exhaustive diagnosis of the city that served as a basis to the current monitoring program that includes a detailed annual citizen survey. Results showed that the lowest levels of quality of life and human development indices were concentrated in 20% of the total urban territory; including those areas (comunas) where Metrocable was planned (see Fig. 2). They were characterized by dramatic socioeconomic conditions, exposure to social exclusion and spatial segregation, and their predisposition to the occurrence of crimes and violence. Furthermore, terrains had high vulnerability levels to natural risk (due to e.g. topography), and high environmental degradation. They also showed typical peripheral location characteristics, with highly dense urban expansion and territorial disorder resulting from irregular development. They lacked in public infrastructure and insufficient government investment as well as private appropriation of public spaces. All this affected mobility and travel security, lengthening travel times within the neighborhood and transport systems connecting with the rest of the city. At institutional level, a history of inappropriate public interventions created dissatisfaction, and the existence of a widespread regulatory ignorance (Puerta Osorio 2011).

In the light of these results, the government decided to intervene through upgrading programs designed on a case-to-case (see Fig. 2). These interventions aimed at providing equal opportunities to all city residents, especially those traditionally excluded, and get both a territorial and social balance based on the following areas of action (Puerta Osorio 2011):

1) The improvement of the urban environment with a specific focus on mobility and accessibility, especially for pedestrians. These infrastructure interventions included the construction and improvement of collective facilities such as libraries, health centers, schools and urban parks, and transit infrastructures like bridges and walkways. Altogether, they generated new public spaces and social facilities, turning them into elements of social cohesion, promoting ownership, collectivism and carefulness. The insertion of population into the health care and education system became a number one priority (Blanco and Kobayashi 2009). Housing conditions were also improved through regularization, rehabilitation, and new development. In addition, the work created in the construction sector (a share of the workers had to be chosen from the local community) fostered the local economy

(Arenas Madrigal and Arenas Madrigal 2015; Bateman et al. 2011). Authorities also launched social programs: child protection, social reintegration, and support of victims of human rights violations, among others. Environmental care was also advanced through wildlife conservation, rehabilitation of degraded environmental spaces and improved water treatment (P. Brand and Dávila 2011; J. Dávila and Daste 2011; J. Dávila, Daste, and Millan 2015).

2) The strengthening of citizen involvement, key to the subsequent local appropriation of the services and equipment generated. Participatory planning processes legitimized actions on the territory through NGOs and Community Local Administrative Action Boards, creating spaces for discussion, exchange, and dissemination. Community involvement occurred before, during and after the infrastructure works, regardless of social roles. A wide variety of participation tools were used: tours, committee meetings and other public meetings, workshops and training processes, census, inter-institutional coordination activities, open calls, home visits, dissemination and promotion campaigns, free press (number of letters) and information booths, conferences and social events. Already at the diagnostic phase, citizens were involved to identify key areas together with technical teams. At the project design phase, they were involved in the decision-making of intervention projects looking both at social and economic feasibility. When projects were finalized, dissemination and appropriation was successfully done though different cultural activities where all Medellin citizens were invited to show the renovated image among all Medellin population, creating pride among locals (Farajado Valderrama, Cabral, and Tonkiss 2014).

3) The strengthening of institutions through transparency, communication, predefined management distribution, decentralization and empowerment of local entities. Transparent institutional coordination reversed the established culture of corruption, inefficiencies and illegality. Over 20 municipal departments participated in managerial assembles together with civil society and private organizations as well as international cooperation agencies. Financing was on the premise that the development of the neighbour could be self-financing at one stage, due to the proper management of public finances (Carvajal 2009; J. Dávila and Daste 2011). For this, the administration put in place strategies as permanent accountability worthy taxpayer assistance, publicity and responsibility of taxpayers, besides regular updates of cadastral values in the area (Echeverri and Orsini 2011).

Together, these measures increased the quality of life for Medellin population and minorities in particular. Urban upgrading projects achieved to work with and for the community on the different proposals and intervention designs. This may have led to synergies between participatory urban planning and the development of new public spaces and transport infrastructure, promoting ownership of the environment, and close bonds of trust within and between communities and authorities; thus making them feel taken into account regarding their views improving social interactions.

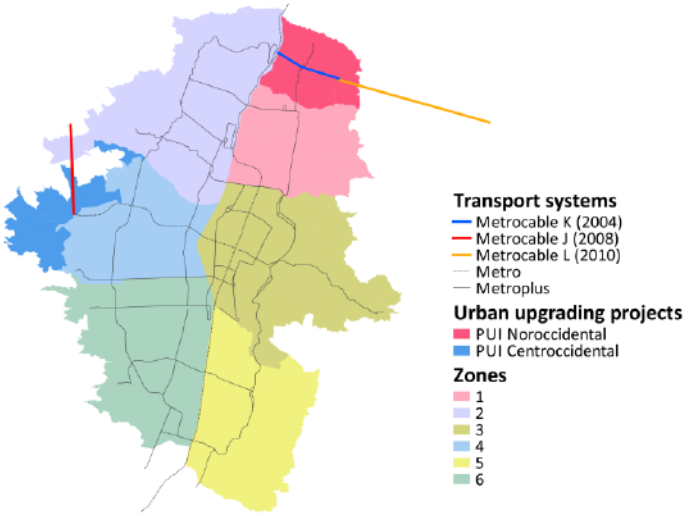

Figure 2 Medellin: Zones, TOD and urban upgrading projects distribution for the study period area.

The Medellin case has been studied already, but so far none has compared the effect of TOD changes on social sustainability in general and social capital in particular. (Cerda et al. 2012) showed that the enhancement of physical structures reduced violence in Medellin for their study period (2003-2008). However, with their study period they focused only on the Metrocable infrastructure, as it is the only one finished at that time, and results may be influenced by the relative violence reduction due to the peace process in the region[3] (Velásquez-Castañeda 2014). (Bocarejo Suescún and Velásquez Torres 2011) and (Agudelo Vélez et al. 2011) studied the neighbour impact of the first Metrocable line between 2000 and 2005. (Bocarejo Suescún and Velásquez Torres 2011) found an increase in the Hansen accessibility index in the neighbour and (Agudelo Vélez et al. 2011) also measured some social indicators but with inconclusive result. (Peter Brand and Dávila 2011) discuss the feeling of inclusion and integration among the citizens of the intervention areas, but they do not explicitly cover the issue of social capital. Other studies discuss in detail the so-called "PUI methodology" and highlight its transformative power, based not only on infrastructure and institutional change but also on the understanding of the socio-spatial fundamentals ant the community-oriented planning (Blanco and Kobayashi 2009; P. Brand 2010; J. Dávila 2014; Echeverri and Orsini 2011; Fukuyama and Colby 2011; Hylton 2007). Finally, others investigate microenterprise development to foster sustainable development (Bateman et al. 2011) and the impact of the participative budgets (Carvajal 2009) and the major´s perception (J. Dávila 2009) on governance transparency and consequently, institutional renewal.

The case study of (J. Dávila 2012a) is the only one that highlight the social and environmental synergies of the Medellin case. Although the original drive for transit infrastructure development hinged on social and mobility considerations, potential environmental effects were considered at some point (Alcaldía de Medellin 2015; Metro de Medellin 2015a; Metro de Medellin 2015b). According to this

[3] In fact, the homicide rate between 2008 and 2010 increased (Velásquez-Castañeda 2014).

baseline, the replacement of the fossil fuel operating vehicles by a system of hydroelectric-powered aerial cable cars was projected to contribute to a reduction of up to 121,000 tCO_2 between 2010 and 2016; a reduction of 62,4 % compared to the baseline emission scenario[4]. Additionally, the volumes of trans-boundary air pollutants (mainly carbon monoxide and sulphur dioxide) dropped as baseline modes of transport are replaced with a system relying on electricity generated, predominantly through the use of renewable resources (CDM Executive Board, Grütter Consulting, and TÜV SÜD Industrie Service GmbH 2009). However, the study does not measure the social and/or economic consequences of the Metrocables due to methodological difficulties, assuming it can be said to be largely positive.

None of the above studies quantify the effect of TOD increases in social capital systematically. We here fill the gap and evaluate the enhancement of the quality of life in general and social capital in particular, resulting from Medellin's TOD development and its participatory processes, by post/ante comparison of TOD and non-TOD communities.

4. Study design and methods

In order to evaluate the effect of changes on TOD modal shares and participatory planning interventions on citizen´s quality of life, social sustainability and inequalities reduction, we use the Medellin citizen survey "Medellin como vamos" (Medellin como vamos 2015). We compare the responses between the years 2009 and 2012 on different aspects, including social capita. The period selection is based on the following: according to the public evaluation reports more than 80% of the infrastructures related to participatory TOD planning were finished by 2012, enough to consider this year as a post-evaluation date. Although the lines K and J of Metrocable were opened before, the effect of the upgrading programs could only be observed after 2010 when the construction phase began to an end, hence 2009 could be considered a pre-intervention year (Alcaldía de Medellín 2004; Alcaldía de Medellín 2008; Alcaldía de Medellín 2012; Arenas Madrigal and Arenas Madrigal 2015; Puerta Osorio 2011). This said, the number of survey questions comparable is highest between 2012 and 2009 years. Finally, due to the success of the first two upgrading programs in zones 1 and 4, following interventions using the same design were implemented in other parts of the city, which effect –based again on the finalization of the construction phase -could alter the results.

We use the changes in TOD modal share as the dependent variable and compare the survey scores on issues that cover the socioeconomic status, the satisfaction with public intervention and the social capita of the respondents. The survey answers are

[4] Baseline emissions were defined as those that would have resulted from the use of other modes of transport to cover the required origin and destination distances. Medellin´s modes available were minibuses, taxis and jeeps using fossil fuels such as petrol and diesel (CDM Executive Board, Grütter Consulting, and TÜV SÜD Industrie Service GmbH 2009).

available for three comparison groups besides Medellin average: geographic zones, income levels, and gender; for our analysis we use all independently.

4.1 Grouping variable: changes in the use of TOD modes

For each comparison group, we first identify which group (e.g. for gender: male, female or both) show a change in commuting behaviour towards typical TOD modes (bus, metro, bike and walk) at the expense of non-TOD modes (private car, motorcycle and taxi). We look at the change in modal shares between 2009 and 2012 to select our case and control groups. For each comparison group, TOD groups include those where there has been a positive change in TOD modes (TOD), and non-TOD groups those groups where the use of TOD modes has remained stable or decreased (n-TOD).

4.2 Independent variables

In the survey, the questions are presented in 16 different topic categories. We regroup them into the following three: socioeconomic variables, perception of public intervention, and social capita. Each topic category consists of different variables (aspects) (Table 1). We use the literature review to define social capital and socioeconomic variables according to the dimensions and influencing factors identified.

For data preparation we use feature scaling, a method used to normalize from nominal and ordinal to scale values and further rescaling to the [0, 1] range, allowing us to use 187 questions of the survey. In addition, 12 questions were also reversed to have homogeneous scale direction.

Table 1 Study design: variables, survey questions, and groups in the study sample

N	Topic category / Variable name	N° questions (187)	Groups	Group description
	Socioeconomic variables	**8**	**Medellin**	Medellin average
1	Housing	3	**Income**	Low (L); Mean (M); High (H)
2	Education	3	**Zones**	1, 2, 3, 4, 5, 6
3	Income	2	**Gender**	Female (F); Male (M)
	Pub Intervention	**89**		
4	Education (satisfaction)	1		
5	Environment	16		
6	Health	3		
7	Public Infrastructure	26		
8	Public space	27		
9	Transit	16		
	Social capita	**90**		
10	Collective action	6		
11	Groups and Networks	16		
12	Information and communication	15		
13	Social inclusion	35		
14	Trust	18		

For the comparison analysis, we first calculate the % change between 2009 and 2012 for each variable and topic category ("Change"). We are also interested in the

rate of homogenization between different groups, to evaluate if the interventions have not only been effective within the area, but also reduce inequalities, as it is read in the planning programs "for a just city" (Alcaldía de Medellin 2015; Alcaldía de Medellín 2004; Alcaldía de Medellín 2008; Alcaldía de Medellín 2012; P. Brand 2010). Hence, in order to evaluate the homogenizing effect –meaning, reducing inequalities between group scores- we compare the different groups with Medellin average. To do so, we calculate the deviation to Medellin average ("Deviation") for 2009 and 2012 determined by the ratio between each group score and the Medellin average score. This gives a value below or above 1, where =1 tells that the value is equal to Medellin average, <1 means that it the group scores worse, and <1 means that it the group scores better than Medellin average. We then calculate "Change in deviation", which is the % change of "Deviation" for each group.

Finally, we compare TOD and n-TOD groups for the % changes in "Change" and "Change in deviation" to see whether TOD changes influence the socioeconomic variables, perception of public intervention, and social capita. We use the Wilcoxon Mann-Whitney Rank Sum Test, a nonparametric test with the null hypothesis that two samples come from the same population against an alternative hypothesis, that a particular population tends to have larger values than the other. It is used when the dependent variable (in our case "Change" and "Change in deviation") can be assumed that it is at least ordinal but cannot be assumed it has a normal distribution[5]. For each statistical test run we report the median (M) of each group, the z and p values.

5. Results

This section presents the main results, divided into two main parts. First we report the TOD-modal changes between 2009 and 2012 for all groups to identify TOD and n-TOD groups for the different zones, income levels and gender.

5.1 TOD-modes increased in 5 groups

TOD-modes changed in all groups between 2009 and 2012. TOD-modes increased in zones 1, 2, and 4, as well as in the low income and female group. On the contrary, zones 3, 5 and 6, middle and high income, and the male group show a decrease in TOD-modes (see Figure 3). Hence, in the urban upgrading intervention areas (1 and 4) there has been an increase in the use of TOD-modes, and presuming these are the areas with higher concentration of population with low incomes, the changes in the income comparison group is not surprising. Crucially, insecurity issues in mobility for women had also been a number one priority in the urban upgrading programs. Hence- and considering the high concentration of positive TOD-modes in lower areas- these variations may indeed indicate a great success of the intervention for low and mid income women previously reluctant to use transit modes for security issues.

[5] Different graphical and numerical methods were used to dismiss normal distribution in all variables included in the analysis for all groups.

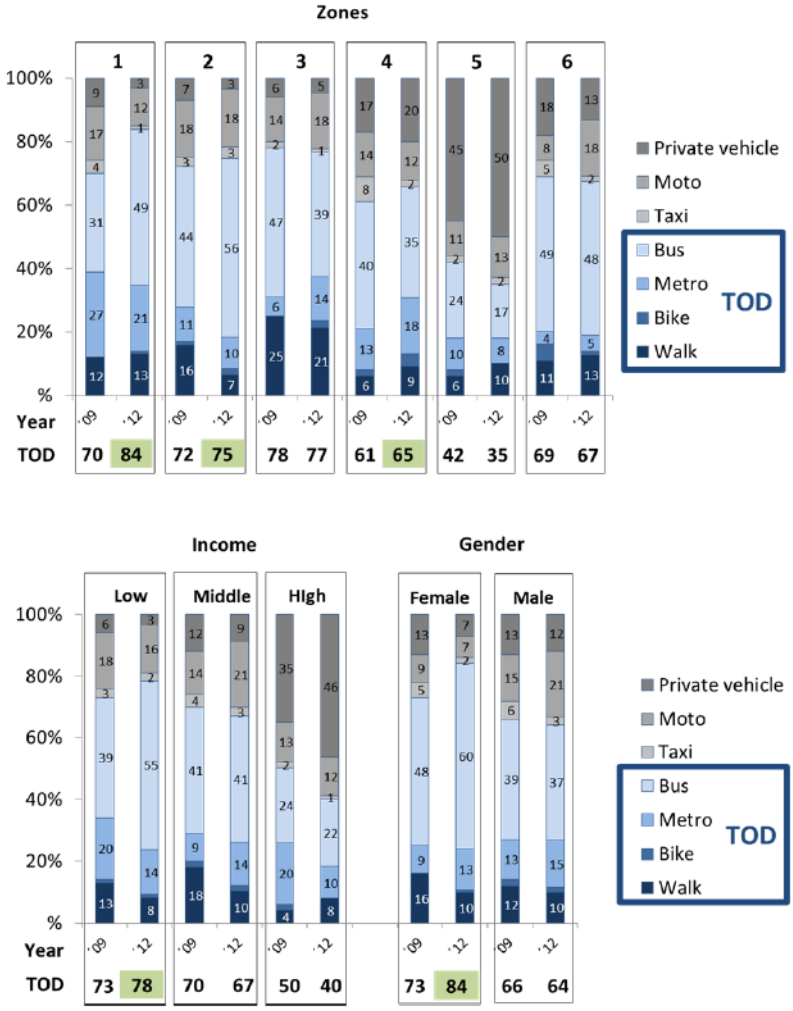

Figure 3 Modal shares changes between 2009 and 2012 for the study groups.

5.2 Variable scores, deviation to Medellin average and group comparison

Table 1 reports the score of the different variables and topic categories for all groups for both 2009 and 2012. Values range from 0 to 1, where 0 is the minimum and 1 the maximum. Overall, there is a general increase in the scores for all socioeconomic variables, perception of public intervention and social capital. However these changes are different for each topic category, variables and groups. For all the groups included, housing shows the lowest scores among the socioeconomic variables. Income improves; education deteriorated from 2009 until 2012 in all zones. Regarding citizen´s perception on public intervention and social capita satisfaction with education is the only one decreasing among all groups accordingly with education quality. Health and transit slightly decrease for Medellin average, but this tendency differs among groups. Satisfaction with policies aiming a enhancing the environment and public infrastructure increase while public infrastructure remains constant. Social capital variables also score very different depending on the dimension we look at. Whereas collective action and trust have rather high scores, groups and networks and information and communication scores are surprisingly low. Overall, although Medellin averages show minor changes, positive and negative changes are clustered according to different groups. We

further analyse this variation by looking at "Change in deviation" and the results of the statistical analysis.

Table 2 Absolute scoring of the variables for the years 2009(I) and 2012 (II) ("Change") (see Fig. A.1 for illustration).

Group		Medellin				Zone									
Subgroup		Average		1		2		3		4		5		6	
Year		I	II	I	II	I	II	I	II	I	II	I	II	I	II
Topic category	**Variable**														
Socioec. variables	1 Housing	0.35	0.38	0.26	0.26	0.31	0.35	0.31	0.36	0.38	0.48	0.50	0.54	0.37	0.28
	2 Education	0.70	0.66	0.73	0.70	0.71	0.64	0.71	0.68	0.73	0.67	0.67	0.64	0.67	0.64
	3 Income	0.81	0.87	0.72	0.79	0.81	0.86	0.80	0.86	0.83	0.89	0.91	0.96	0.81	0.84
Public Intervent.	4 Education (satisfaction)	0.84	0.79	0.81	0.77	0.85	0.80	0.86	0.76	0.83	0.85	0.87	0.82	0.81	0.73
	5 Environment	0.42	0.44	0.44	0.46	0.43	0.48	0.40	0.41	0.38	0.46	0.42	0.42	0.44	0.42
	6 Health	0.54	0.53	0.52	0.52	0.50	0.49	0.59	0.53	0.52	0.52	0.58	0.64	0.55	0.50
	7 Public Infrastructure	0.80	0.85	0.77	0.82	0.78	0.85	0.77	0.83	0.82	0.85	0.84	0.88	0.81	0.85
	8 Public space	0.55	0.55	0.54	0.57	0.56	0.52	0.55	0.53	0.55	0.57	0.57	0.54	0.54	0.57
	9 Transit	0.66	0.65	0.64	0.66	0.69	0.65	0.71	0.62	0.62	0.65	0.69	0.64	0.62	0.65
Social Capita	10 Collective action	0.74	0.72	0.73	0.78	0.71	0.69	0.79	0.62	0.69	0.77	0.80	0.75	0.69	0.69
	11 Groups and Networks	0.21	0.21	0.18	0.18	0.22	0.20	0.18	0.15	0.21	0.27	0.27	0.30	0.20	0.15
	12 Inf. & Commun.	0.42	0.43	0.37	0.42	0.44	0.43	0.42	0.43	0.44	0.45	0.47	0.48	0.38	0.40
	13 Social inclusion	0.49	0.50	0.46	0.52	0.49	0.53	0.51	0.49	0.48	0.49	0.52	0.50	0.46	0.48
	14 Trust	0.61	0.64	0.61	0.65	0.58	0.66	0.63	0.64	0.58	0.63	0.65	0.64	0.61	0.63
Socioeconomic variables		0.62	0.64	0.57	0.58	0.61	0.62	0.60	0.63	0.64	0.68	0.69	0.72	0.61	0.58
Pub. intervention		0.64	0.63	0.62	0.63	0.64	0.63	0.65	0.62	0.62	0.65	0.66	0.65	0.63	0.62
Social Capita		0.49	0.50	0.47	0.51	0.49	0.50	0.51	0.47	0.48	0.52	0.54	0.53	0.47	0.47
Total		0.58	0.59	0.55	0.58	0.58	0.58	0.59	0.57	0.58	0.62	0.63	0.64	0.57	0.56

Table 2 cont.

Group			Income						Gender			
Subgroup			Low		Middle		High		Female		Male	
Year			I	II	I	II	I	II	I	II	I	II
Topic category		Variable										
Socioec variable	1	Housing	0.26	0.37	0.36	0.33	0.47	0.31	0.29	0.55	0.36	0.34
	2	Education	0.71	0.68	0.71	0.65	0.63	0.58	0.71	0.71	0.72	0.65
	3	Income	0.74	0.80	0.82	0.87	0.90	0.95	0.80	0.85	0.77	0.84
Public Inter.	4	Education (satisfaction)	0.83	0.79	0.83	0.77	0.85	0.83	0.84	0.80	0.82	0.76
	5	Environment	0.44	0.46	0.41	0.44	0.39	0.44	0.42	0.46	0.42	0.45
	6	Health	0.53	0.52	0.53	0.51	0.52	0.55	0.53	0.52	0.53	0.51
	7	Public Infrastructure	0.76	0.83	0.80	0.85	0.85	0.87	0.79	0.85	0.80	0.85
	8	Public space	0.55	0.55	0.55	0.55	0.53	0.56	0.55	0.56	0.55	0.54
	9	Transit	0.65	0.66	0.66	0.64	0.67	0.64	0.63	0.61	0.65	0.64
Social Capita	10	Collective action	0.73	0.69	0.75	0.71	0.77	0.74	0.66	0.70	0.75	0.71
	11	Groups and Networks	0.16	0.21	0.19	0.19	0.25	0.31	0.18	0.19	0.21	0.19
	12	Inf. & Commun.	0.39	0.44	0.42	0.42	0.46	0.45	0.40	0.42	0.43	0.43
	13	Social inclusion	0.45	0.52	0.48	0.48	0.51	0.50	0.46	0.50	0.49	0.51
	14	Trust	0.60	0.66	0.60	0.63	0.64	0.63	0.61	0.65	0.60	0.64
Socioeconomic variables			0.57	0.62	0.63	0.62	0.67	0.62	0.60	0.70	0.62	0.61
Pub. intervention			0.63	0.63	0.63	0.63	0.64	0.65	0.63	0.63	0.63	0.63
Social Capita			0.46	0.50	0.49	0.48	0.52	0.53	0.46	0.49	0.50	0.50
Total			0.55	0.59	0.58	0.58	0.61	0.60	0.56	0.61	0.58	0.58

Displaying Medellin´s inequalities, Table 3 shows the percent change of the groups' deviation to Medellin averages between I and II ("Change in deviation"), including all socioeconomic, public intervention and social capita variables. Results show that most positive changes in scores happen in those groups where I values were below Medellin average (bold numbering), indicating a reduction in inequalities between high-scored and low-scored groups, and consequently, among the whole urban population. This effect is more observable for the TOD groups - zones 1, 2 and 4, low income and female group.

Table 3 Equity effect ("Change in deviation") (in %)

			TOD					**n-TOD**					
Topic category		**Variable**	**1**	**2**	**4**	**Low**	**Female**	**3**	5	6	Middle	High	Male
Socioeconomic variables	1	Housing	**-0,05**	**0,04**	0,19	**0,31**	**0,77**	**0,09**	0,01	-0,30	-0,12	-0,38	-0,12
	2	Education	0,01	-0,04	-0,02	0,02	0,05	0,03	**0,02**	**0,00**	-0,04	**-0,03**	-0,04
	3	Income	**0,03**	**-0,01**	0,01	**0,02**	**0,00**	**0,01**	0,00	**-0,03**	-0,01	-0,01	**0,02**
Public Intervention	4	Education (satisfaction)	**0,01**	0,01	**0,08**	**0,01**	0,01	-0,06	0,00	**-0,04**	**-0,02**	0,04	**-0,01**
	5	Environment	-0,01	0,06	**0,14**	-0,01	0,03	**-0,02**	-0,06	-0,10	**0,01**	**0,06**	0,00
	6	Health	**0,02**	**0,00**	**0,01**	**0,00**	**0,00**	-0,09	0,12	-0,07	**-0,03**	**0,08**	**-0,02**
	7	Public Infrastructure	**0,00**	**0,03**	-0,03	**0,02**	**0,01**	**0,03**	-0,01	-0,01	-0,01	-0,04	0,00
	8	Public space	**0,05**	-0,07	**0,04**	**0,00**	0,02	-0,04	-0,04	**0,06**	0,00	**0,05**	**0,00**
	9	Transit	**0,06**	-0,03	**0,07**	**0,05**	**-0,01**	-0,10	-0,05	**0,07**	-0,01	-0,02	**0,01**
Social Capita	10	Collective action	**0,10**	**-0,01**	**0,14**	**-0,03**	**0,08**	-0,20	-0,03	**0,02**	-0,03	-0,01	-0,03
	11	Groups and Networks	**0,04**	-0,08	0,30	**0,38**	**0,04**	**-0,15**	0,10	**-0,26**	**-0,02**	0,29	-0,09
	12	Inf. & Commun.	**0,11**	-0,07	-0,03	**0,09**	**0,01**	-0,01	-0,02	**0,04**	-0,05	-0,04	-0,03
	13	Social inclusion	**0,10**	0,05	**0,00**	**0,13**	**0,05**	-0,07	-0,07	**0,01**	**-0,03**	-0,06	0,01
	14	Trust	0,02	**0,08**	**0,03**	**0,04**	0,02	-0,03	-0,05	-0,03	**-0,01**	-0,06	**0,00**
Socioeconomic variables			**0,01**	**-0,01**	0,03	**0,06**	**0,15**	**0,03**	0,02	**-0,07**	-0,04	-0,10	**-0,03**
Public Intervention			**0,02**	0,00	**0,04**	**0,01**	**0,01**	-0,05	-0,01	**-0,01**	-0,01	0,02	**0,00**
Social Capita			**0,07**	**0,01**	**0,06**	**0,07**	**0,04**	-0,09	-0,03	**-0,01**	-0,03	-0,01	-0,02
Total			**0,03**	**0,00**	0,05	**0,04**	**0,07**	-0,03	-0,01	**-0,03**	-0,03	-0,03	-0,02

Note: bold format: 2009 values (I) below Medellin 2009(I) average.

Finally, Table 4 shows the results of the Wilcoxon-Mann-Whitney test between TOD and non-TOD groups for both the % change in score ("Change") and the % change in the deviation to Medellin mean ("Change in deviation") for the study period. Our results suggest that there is a statistically significant difference between the underlying distributions of the total "Change in deviation" and "Change" of TOD groups and non-TOD groups for all three comparison groups -geographic zones ("Change": z= 6.93, p =0.00; "Change in deviation": z = 8.46, p =0.00), income levels ("Change" : z=4.71, p =0.00; "Change in deviation": z = 6.64, p =0.00), and gender ("Change": z = 2.82, p =0.00; "Change in deviation": z = 4.05, p

=0.00)-. TOD groups show a higher rank sum than non-TOD, indicating that TOD may increase the quality of life besides reducing transport emissions.

There is no statistical difference for the socioeconomic and public intervention variables (except from geographic zones ("Change in deviation": z = 4.22, p =0.00), and income level ("Change in deviation": z = 3.37, p =0.00), with higher scores for the TOD groups in both cases. However, social capita has a statistically significant difference in both "Change" and "Change in deviation" between TOD and n-TOD for all three comparison groups -zones ("Change": z = 7.13, p =0.00; "Change in deviation": z = 7.50, p =0.00), income levels ("Change": z=5.07, p =0.00; "Change in deviation": z = 6.07, p =0.00), and gender ("Change": z = 2.96, p =0.00; "Change in deviation": z = 3.96, p =0.00). TOD groups have higher rank sum than non-TOD groups, indicating that positive changes in TOD use also increases social capita.

At the variable level, although housing, education and income typically show higher medians for TOD groups, particularly for housing, none of them are statistically significant. With regards to the variables looking at the perception of public intervention, only environmental and transit interventions show statistical differences for zones and income levels with TOD groups having higher scores.

Table 4 Statistical results for the comparative groups for all variables: median (M) z and p values (*significant at p < 0.01, grey coloured).

			Zones				Income				Gender			
			Change		Change in deviation		Change		Change in deviation		Change		Change in deviation	
Variables/ Topic category		Values	TOD	n-TOD	TOD	n-TOD	TOD	n-TOD	TOD	n-TOD	TOD	n-TOD	TOD	n-TOD
1	Housing	M	0.60	0.05	0.02	-0.03	0.35	-0.26	0.31	-0.25	0.91	-0.03	0.77	-0.12
		z; p	0.84; 0.40		1.01; 0.31		2.32; 0.02		2.32; 0.02		1.96; 0.05		1.96; 0.05	
2	Education	M	-0.05	-0.03	-0.01	-0.01	-0.04	-0.08	0.02	-0.02	-0.04	-0.07	0.02	-0.07
		z; p	-0.66; 0.51		-0.57; 0.57		1.03; 0.30		1.03; 0.30		1.09; 0.27		1.53; 0.13	
3	Income	M	0.02	0.00	0.00	-0.02	0.01	0.01	0.00	-0.01	0.01	0.03	0.00	0.01
		z; p	0.44; 0.66		1.06; 0.29		0.37; 0.71		0.98; 0.33		-0.31; 0.75		0.31; 0.75	
4	Education (satisfaction)	M	-0.05	-0.09	0.01	-0.04	-0.05	-0.05	0.01	0.01	-0.05	-0.06	0.01	-0.01
		z; p	1.96;0.05		1.94; 0.05		0.00; 1.00		0.00; 1.00		1.00; 0.32		1.00; 0.31	
5	Environment	M	0.10	-0.01	0.06	-0.03	0.01	0.05	-0.02	0.05	0.03	0.02	0.01	0.00
		z; p	3.33; 0.00*		3.61; 0.00*		-1.38; 0.17		-3.63; 0.00*		0.41; 0.68		1.17; 0.25	
6	Health	M	-0.08	-0.09	-0.03	-0.04	-0.05	-0.04	0.00	0.00	-0.06	-0.05	0.00	-0.02
		z; p	0.49; 0.63		0.84; 0.40		0.26; 0.79		0.26; 0.80		-0.22; 0.83		0.65; 0.51	
7	Public Infrastructure	M	0.04	0.02	0.00	0.00	0.06	0.01	0.01	-0.01	0.03	0.04	0.01	0.00
		z; p	0.18; 0.85		0.64; 0.52		1.62; 0.10		3.62; 0.00*		0.85; 0.40		1.56; 0.12	
8	Public space	M	0.00	-0.02	0.05	-0.01	0.01	0.02	0.03	-0.01	-0.02	-0.01	0.02	0.00
		z; p	-0.01; 0.99		1.53; 0.12		-0.13; 0.90		0.78;0.43		0.32; 0.75		0.99; 0.32	
9	Transit	M	0..02	-0.06	0.04	-0.03	0.02	-0.03	0.03	-0.01	-0.03	0.00	-0.01	0.01
		z; p	2.95; 0.00*		3.07; 0.00*		2.86; 0.00*		2.71; 0.00*		-1.47; 0.14		-2.83; 0.01	
10	Collective action	M	0.06	-0.08	0.09	-0.05	-0.04	-0.04	-0.02	-0.03	0.07	-0.06	0.06	-0.04
		z; p	2.75; 0.00*		3.04; 0.00*		0.00; 1.00		0.28; 0.78		1.92; 0.05		1.76; 0.07	

Table 4 cont.

11	Groups and Network	M	0.15	-0.12	0.15	-0.14	0.31	0.15	0.15	0.12	0.08	-0.03	0.05	-0.12
		z; p	4.05; 0.00*		4.33; 0.00*		1.11; 0.27		0.92; 0.36		1.85; 0.06		3.77; 0.00*	
12	Inf & Communication	M	0.07	-0.02	0.03	-0.02	0.06	-0.03	0.05	-0.03	0.03	-0.04	0.02	-0.03
		z; p	1.50; 0.13		0.95; 0.34		3.06; 0.00*		2.94; 0.00*		1.14; 0.25		1.80; 0.07	
13	Social Inclusion	M	0.09	-0.01	0.05	-0.04	0.12	0.00	0.07	-0.04	0.08	0.06	0.03	0.02
		z; p	4.73; 0.00*		5.60; 0.00*		3.94; 0.00*		5.74; 0.00*		1.49; 0.14		1.24; 0.22	
14	Trust	M	0.09	-0.01	0.03	-0.03	0.08	0.02	0.03	-0.01	0.08	0.07	0.01	0.01
		z; p	3.20; 0.00*		3.61; 0.00*		2.38; 0.01		3.27; 0.00*		0.28;0.77		0.41; 0.68	
Socioeconomic variables		**M**	0.17	0.01	0.01	-0.02	0.12	-0.04	0.05	-0.04	0.21	-0.04	0.15	-0.08
		z; p	0.74; 0.46		0.76; 0.45		2.39; 0.02		3.37; 0.00*		1.89; 0.06		2.42; 0.02	
Public Intervention		**M**	0.03	0.00	0.02	-0.01	0.02	0.00	0.01	0.00	0.01	0.01	0.00	0.00
		z; p	2.53; 0.01		4.22; 0.00*		0.95; 0.34		1.77; 0.08		0.22; 0.83		0.8; 0.43	
Social Capita		**M**	0.09	-0.02	0.05	-0.04	0.11	0.00	0.06	-0.02	0.07	0.02	0.02	0.00
		z; p	7.13; 0.00*		7.50; 0.00*		5.07; 0.00*		6.07; 0.00*		2.96; 0.00*		3.98; 0.00*	
Total		**M**	0.05	-0.01	0.03	-0.02	0.07	0.00	0.04	-0.01	0.05	0.01	0.01	0.00
		z; p	6.93; 0.00*		8.46; 0.00*		4.71; 0.00*		6.64; 0.00*		2.82; 0.00*		4.05; 0.00*	

The variables measuring social capital are statistically significant, with the exception of information and communication, maybe because this dimension requires more time for changes to be observed. For the income levels however, information and communication is statistically significant together with social inclusion and trust. The comparison group gender only shows statistic significant results for groups and networks both at the variable and topic category level.

Overall, TOD groups show an increase not just in the quality of life, but also in social capital. At the outset, inequality dominated in TOD groups, an observation that legitimises the equity intention of the interventions. As a result of the TOD interventions, the previously disadvantaged parts of Medellin improved and became less disadvantaged. Pointedly, among TOD zones, zone 1 demonstrates better results than zone 4. Possibly this is due to the fact that the PUI Noroccidental (zone 1) started before the PUI Centroccidental (zone 4) and the works were more advanced (Puerta Osorio 2011).

6. Discussion

Urban planning in general and TOD in particular will be fundamental in tackling the social and environmental challenges to come in cities due to climate change (Fernandez Milan and Creutzig 2015). While TOD and participative urban planning emerges as an increasing popular urban measure, the potential of TOD interventions on social capital when citizen's participation takes place in the process remains underexploited. TOD often faces challenges related to inefficient public participation processes and unstructured stakeholder involvement which may lead to project designs at odds with local needs and suboptimal outcomes in social sustainability (Assefa and Frostell 2007; Kathryn Scott 2000; Soria-Lara, Bertolini, and te Brömmelstroet 2015; Belzer and Autler 2002; Dorsey and Mulder 2013). Participatory TOD planning could avoid such undesired outcome and further increase social and environmental positive effects. Besides the well known TOD

changes in transport emissions and land use mix, participatory approaches enhance the effects on social interactions in two ways. First, TOD itself improves the quality of public spaces and urban connectivity and accessibility. Diverse land use patterns, well-connected street networks and fast, frequent and well-connected TOD modes enhances citizen's urban mobility that in turn fosters social networks. Second, participation fosters transparency, trust, social inclusion, collective action and social networks. In addition, social capital itself leads to sustainable behaviours in the community. For example, the feeling of ownership of the TOD makes usage of TOD more likely. The strengthening of democratic processes; and the empowerment of citizens in the design, implementation, handing over mechanisms and evaluation of TOD plans increases the public welfare and associated social benefit. Numerous methods have proved to be effective in communicating complex matters to citizens –e.g. visual and participative workshops aiming at identifying preferred TOD combinations for citizens (Bailey, Grossardt, and Pride-Wells 2007; Fernandez Milan 2015)-. Hence, TOD and citizen's participation could be used as a catalyser for local sustainability.

Our results have to be understood in the larger context of Medellin´s transformation since the early 2000s until now. During the study period there were many interventions all around the city aiming at similar outcomes that certainly influenced all city areas. However, taking TOD modal changes as the grouping variable, we avoid looking at secondary effects (e.g. zone 2 is included in our TOD group regardless of the development of its upgrading program, not yet finished for the study period). In any case, despite the impressive positive effects of the PUIs, these cannot be considered as the only tool to enhance social and environmental objectives at the city level.

TOD is critical to the achievement of a wide range of social, economic and environmental objectives and, therefore, needs appropriate institutions to ensure its integration with the strategic management of the rest of urban development policy. In Medellin, local political leadership played a key role. An institutional strategy that comprises the processes of decision-making, design, construction and coordination of the multiple civil works, cable equipment procurement, installation and implementation, system operation, and financing of the whole package is fundamental for maximizing outcomes. This should be done by aligning the divergent interests of the greater city, the project municipality, the regional authority and the national government to avoid individual structural intervention from the public transport authorities (Acevedo II; Bahl II; J. Dávila 2014). In this way, the process also enhances local democracy, equality and social regulation and avoids confrontation with unaccepted structural interventions, ultimately maximizing the social results of the intervention (P. Brand 2005).

Medellin´s experience could be used in urban development contexts to come. In Medellin itself, different governments repeated this scheme in other marginalized areas. They have developed an intervention methodology that is showing applicable

in other contexts, provided there is commitment from the government to carry out such innovative urban planning (Cárdenas 2008; J. Dávila IIb). In fact, this methodology has already been adapted to other cities in Colombia and Brazil, and is the bases for the development of the Growth Acceleration Program (J. D. Dávila 2013; Farajado Valderrama, Cabral, and Tonkiss 2014). This is slightly reminiscent of isomorphic development of urban administrations in China, coordinated partially be central governments, and by peer-based learning from frontrunners (F. Creutzig et al. II). Network and learning processes should be leveraged to further upscale the positive experiences with TOD.

7. Conclusion

The extraordinary outcomes of Medellin in the last years is not just a result of the massive public transport investment, but also on the synergies between transport infrastructural interventions and the urban upgrading integration programs in the form of participatory TOD. With this study, we provide new evidence that citizen participation increases the environmental benefits of TOD, and augment the social capital of its participants.

Appendix

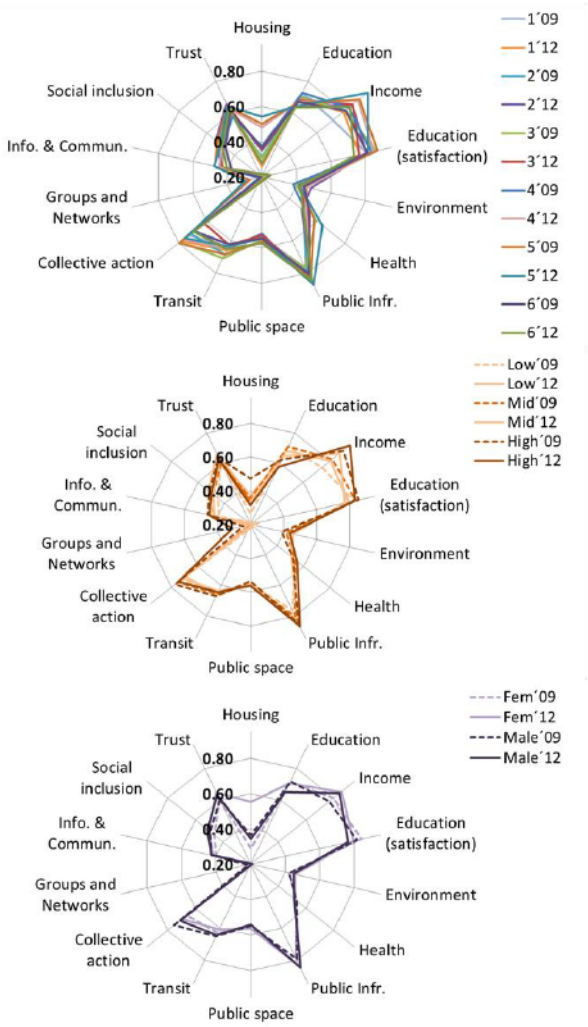

Fig. A.1 Scoring of the variables for the years I and II ("Change") for all three comparison groups: zones, income level and gender (based on the numbers reported in Table 2).

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