🏆 *reviewed paper*

Integrated TOD and Urban Land Use Planning: Evidence from Iran, Kashan

AmirReza Mamdoohi, Iman Farzin, Hadi Gholi

(AmirReza Mamdoohi, Assistant Professor, Faculty of Civil and Environmental Engineering, Tarbiat Modares Universiy, Tehran, Iran, armamdoohi@modares.ac.ir)
(Iman Farzin, PhD Student, Faculty of Civil and Environmental Engineering, Tarbiat Modares Universiy, Tehran, Iran, iman.farzin@modares.ac.ir)
(Hadi Gholi, PhD Candidate, Faculty of Civil and Environmental Engineering, Tarbiat Modares Universiy, Tehran, Iran, hgholi@modares.ac.ir)

1 ABSTRACT

Ignoring mobility in urban development policies leads to social and environmental costs. Therefore, reviewing these policies, in order to reach sustainable mobility, is necessary. This means that urban development programs should be directed towards strategies where walking, cycling and transit are key elements. This approach which is known as transit-oriented development (TOD), focuses on developing communities that push away from the car-oriented urbanism and mobility toward urban forms and land uses that are closely integrated with active, efficient, low-impact and people-oriented urban travel modes: walking, cycling and transit. The focus of this paper is on urban land use planning to shape sustainable mobility in cities, according to TOD principles. First, based on experts and practitioners' opinions and using a Multi-Criteria Decision Making (MCDM) model, most important variables and criteria were determined in order to effective TOD-based urbanism planning. Results showed that criteria related to land use are most important factors from experts' point of view. Then, as the case study from Iran, four bus stations in main squares of the city of Kashan were considered. Information about land use factors around these squares was extracted and analyzed using ArcGIS software, and those stations that are more prone to transit-oriented development, were determined. According to results, 15-Khordad square is an appropriate location for future development. Results can be of help to urban planners in future planning and policies, in order to achieve the sustainable mobility in urban environments.

Keywords: feasibility, MCDM, transit station, land use planning, TOD

2 INTRODUCTION

Sustainable development leads to a new approach in the transport and land use planning. Optimum use of land with approach of reclamation, preventing the sparse growth, increased density and mixed land uses, have been proposed in theories of sustainable development in urban areas. From most important impacts of sustainable development on transport and land use planning, are:

- Coordinating the planning of transit and land use to reduce the tendency to private car.
- The design of urban land use in such a way that access to travel destinations or services would be provided easily, through combination of walking, cycling and transit.
- Strengthening the role of neighborhood units deployed around transit stations, especially stations of rail system.

Today, urbanization and population growth in the process of urban development, and increasing people's dependence on private car, has been caused traffic problems and congestion, parking problems, Increased travel time, inadequate public transport and increased use of lands (Alberti & Waddell, 2000).

In the modern urbanism, urban development and transport cannot be realized independently of each other, because they are closely and undeniably interconnected with each other and with the urban quality standards. Urban development due to urban transport components, has been considered always and has been done with different objectives and methods at different times. In this context, what is emphasized in the Third Millennium is transit-oriented development (TOD) that is dense development with the right mix of land uses in the vicinity of public transport stations and routes (Hrelja, 2015).

Transit-oriented development is a dense development with the right mix of land uses in the vicinity of transit stations and routes. This creates lively neighborhoods with a high quality of life. In this approach, living and working in dense environments with diverse utilities and multiple options for mobility would be possible. Furthermore, TOD will result in Less driving time and will reduce car travel demand (Crane, 2000).

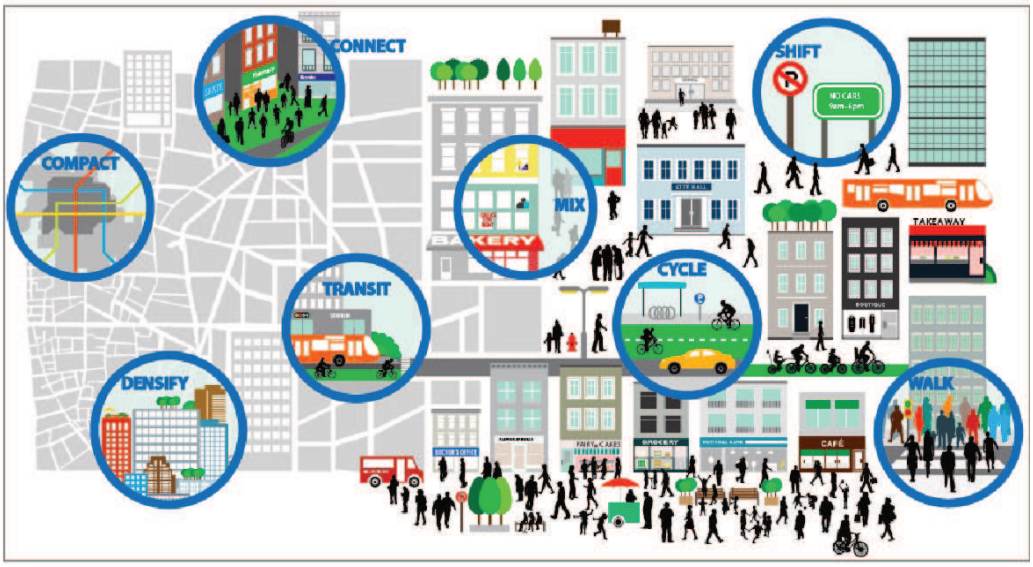
ISBN 978-3-9504173-2-6 (CD), 978-3-9504173-3-3 (print)
Editors: Manfred SCHRENK, Vasily V. POPOVICH, Peter ZEILE, Pietro ELISEI, Clemens BEYER

In the following, definition, principles, objectives, and benefits of TOD are presented in section 3. Then, some evidences about relationship between travel demand and land use characteristics are shown in Section 4. An AHP model was applied on expert opinions about most important TOD factors and results are shown in section 5. After determining the most important TOD vriable (land use), some bus stations in the city of Kashan were investigated as case study, with reference to land use criteria, in section 6. Finally, the paper is concluded in section 7.

3 TRANSIT-ORIENTED DEVELOPMENT (TOD)

Many definitions of transit-oriented development were provided so far. One of the most comprehensive definitions have been provided by Colthorpe, one of leaders of new urbanism movement. He defines TOD in this way: Transit-oriented development is functional combination of land use and public transportation by creating compact, walkable and mixed-use neighborhoods within the walking distance around transit stations. Synthetizing residential, retail, official and public land uses in a walkable environment, facilitates using of public transport, cycling and walking. This type of development, put together individuals, businesses and services, and is designed so that traveling by varios travel modes will become safe, efficient and comfortable (Calthorpe, 1993).

Components of transit-oriented development has been shown in Figure 1. These principles can be applied to creating societies based on public transport and also integrating the development and transportation (Dimitriou & Gakenheimer, 2011).



Source: Institute for Transportation & Development Policy (ITDP)

Fig. 1: Transit-oriented development (TOD) principles

The main objective of the transit-oriented development in most societies is reducing the share of private car. However, such development has other benefits as follows (Curtis, Renne, & Bertolini, 2009; Ramírez & Rosas, 2014):

- Efficient and sustainable use of land, energy and resources.
- Increasing the share of public transport and its profit from fares.
- Reduction of congestion and transportation costs by reducing the share of private car.
- Improvement of air quality and reducing greenhouse gas emissions.
- Ensuring a healthier and more active lifestyle by encouraging people to walking.
- Improving the access to jobs and economic opportunities for business owners and low-income people.
- creation of centralized activities.

European project of integrated transport and land use planning, explicitly states the following suggestion: transportation and land use policies are successful only if necessary criteria for sustainable urban transport

are provided. Foe example: reducing distances and travel times, and reducing the share of private car Such that traveling by car becomes less attractive (slower or more price) (Paulley & Pedler, 2000).

In practice, this definition means that TOD should be lead to more attractive transit, cycling and walking, relative to the private car. People tendency to use transit, cycling and walking is known as sustainable mobility.

Mobility management policies and programs would be result to more efficient travel behavior. This policy can be used as an alternative option to expand road capacity and increase the number of parking. Mobility management affects directly on land use by eliminating the need for more roads and parking. Comprehensive programs to reduce the travel demand by car and achieve sustainable mobility, reduce number of trips usually between 4 to 20 percent during peak periods. Effects of these programs varies according to location and social-economic profile. Programs that have not economic incentives, result usually less than 10% reduction. In downtown areas, these policies will shift the modes of travel to walking and transit (sustainable mobility). While in areas with low density, will be shifted to cycling and carpooling (Moudon & Stewart, 2013).

The aim of mobility management is reducing total traffic in general, and shifting trips by car to other travel modes and increasing the share of cycling and walking during the peak period. In table 1, impacts of these policies on different TOD objectives, have been rated (Su & Zhou, 2012).

Objective	**Rating**
Reduces total traffic.	2
Reduces peak period traffic.	3
Shifts peak to off-peak periods.	2
Shifts automobile travel to alternative modes.	3
Improves access, reduces the need for travel.	1
Increased ridesharing.	2
Increased public transit.	2
Increased cycling.	2
Increased walking.	2
Increased Telework.	2
Reduced freight traffic.	0
Rating from 3 (very beneficial) to –3 (very harmful). 0 indicates no impact or mixed impacts.	

Table 1: Rating the impact of mobility management policies on TOD objectives

4 TRAVEL DEMAND ELASTICITY WITH RESPECT TO LAND USE CHARACTERISTICS

In this section, elasticity in travel demand with respect to changes in land use will be discussed. In this context, Elasticity means that how travel damand will be changed, by doubling factors that affecting travel.

Ewing and Cervero have studied travel demand elasticity with respect to factors such as density, diversity, design and accessibility. Results have been shown in Table 2. Numbers in the table means that, for example, by doubling the density, vehicle trips and vehicle miles traveled (VMT) are decreased by 5% (Poulenez-Donovan & Ulberg, 1994).

Factor	**Description**	**Trips**	**VMT**
Local Density	Residential and employees divided by land area	-0.05	-0.05
Local Diversity (Mix)	Jobs/ residential population	-0.03	-0.05
Local Design	Sidewalk completeness/ route directness and street network density.	-0.05	-0.03
Regional Accessibility	Distance to other activity centers in the region.	---	-0.20
This table shows the elasticity values of vehicle trips and vehicle miles travelled (VMT) with respect to various land use factors.			

Table 2: Travel demand elasticity with respect to some land use factors

ISBN 978-3-9504173-2-6 (CD), 978-3-9504173-3-3 (print)
Editors: Manfred SCHRENK, Vasily V. POPOVICH, Peter ZEILE, Pietro ELISEI, Clemens BEYER

In another study by Madden and Stewart, elasticity of vehicle miles traveled (VMT) and demnd for other modes of travel such as walking and public transport, were calculated with respect to factors such as density, diversity, design, accessibility and distance to the bus station. Results have been shown in Table 3. Numbers in the table means that, for example, by doubling the density of residential areas, vehicle miles traveled (VMT) is decreased by 4%, and using of public transport and walking are increased by 7% (Litman, 2006).

Category	Variable	VMT	Walking	Transit
Density	Household/population density	–0.04	0.07	0.07
	Job density	0.00	0.04	0.01
	Commercial Floor Area Ratio (FAR)	n/a*	0.07	n/a
Diversity	Land use mix	-0.09	0.15	0.12
	Jobs/housing balance	-0.02	0.19	n/a
Design	Distance to a store	n/a	0.25	n/a
	Intersection/street density	-0.12	0.39	0.23
	Percent 4-way intersections	-0.12	-0.06	0.29
Destination accessibility	Job accessibility by auto	-0.20	n/a	n/a
	Job accessibility by transit	-0.05	n/a	n/a
	Jobs within one mile	n/a	0.15	n/a
Distance to Transit	Distance to downtown	– 0.22	n/a	n/a
	Distance to nearest transit stop	-0.05	0.15	0.29

* not applicable

Table 3: Travel demand elasticity with respect to some land use factors

5 EXAMINING THE ROLE OF LAND USE PLANNING IN TOD APPROACH, USING AHP MODEL

Today, what is done in the design of urban systems, is a comprehensive urban development program aimed at creating maximum possible match between urbanism and land use policies on one hand, and urban transportation systems optimized according to the characteristics of the urban network on the other hand. Since each of the bus stops influences over peripheral environment gradually, development planning of stations should be considered with their periphery as a coordinated and interacted set. Many models can be applied in the integrated land use and transport planning. Some of these models are:

- Linear regression
- Fuzzy-GIS
- Neural-fuzzy
- IHWP
- MCDM[1]

In this study, AHP (an MCDM model) has been used. The Analytic Hierarchy Process (AHP), introduced by Thomas Saaty (1980), is an effective tool for dealing with complex decision making, and may aid the decision maker to set priorities and make the best decision. By reducing complex decisions to a series of pairwise comparisons, and then synthesizing the results, the AHP helps to capture both subjective and objective aspects of a decision. In addition, the AHP incorporates a useful technique for checking the consistency of the decision maker's evaluations, thus reducing the bias in the decision making process (Dodgson, Spackman, Pearman, & Phillips, 2009).

The AHP considers a set of evaluation criteria, and a set of alternative options among which the best decision is to be made. It is important to note that, since some of the criteria could be contrasting, it is not true in general that the best option is the one which optimizes each single criterion, rather the one which achieves

[1] Multi-criteria decision making

the most suitable trade-off among the different criteria. The AHP generates a weight for each evaluation criterion according to the decision maker's pairwise comparisons of the criteria (Dodgson et al., 2009).

At first, as shown in figure 2, two variables and eight criteria was selected. In order to evaluating preferences about these variables and criteria, a questionnaire was designed and distributed among experts. Four questionnaires were completed and after proccessing, following weights (table 4) were obtained. As it clear, in gereral, criteria related to land use vriable are most important factors for future development.

Variables	Criteria	Weights of criteria	Weights of variables
Land use	population/ residential density	0.266	0.787
	mixing and diversity	0.342	
	station complexes development	0.161	
Design	walk-friendly/ cycling friendly	0.183	0.027
	parking limit	0.285	
	continuity and connection to passages	0.113	
	accessibility to services	0.086	
	active space	0.105	

Table 4: TOD variables and criteria weights based on expert's opinion

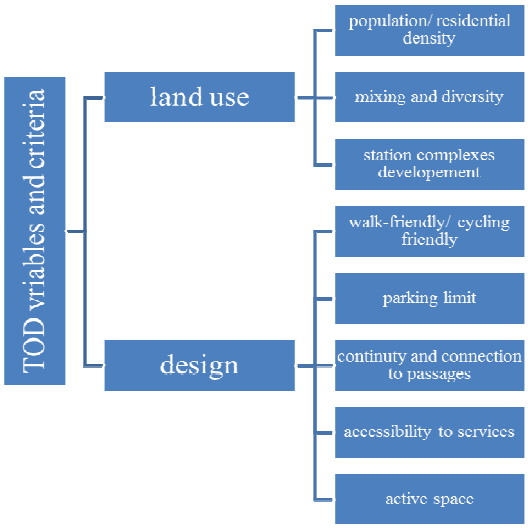


Fig. 2: Examined TOD variables and criteria

Questionnaires were distributed and inconsistency index, for all criteria and variables, were obtained 0.03 (namely less than critical value of 0.1). The importance of inconsistency rate is in preliminary verification of paired comparisons data and using them in decision-making. If the inconsistency rate is higher than 0.1, matrix of paired comparisons data will have little validity. Resulted inconsistency rate of less than 0.1, indicating appropriate reliability of information which was obtained from the questionnaires.

6 EVALUATING THE POTENTIAL OF BUS STATIONS IN THE CITY OF KASHAN FOR TOD

Kashan city is located in the northern of Isfahan province, in the center of Iran. Kashan and suburbs bus company was founded in 1991. Currently, 159 civilian buses and 35 buses of private sector are in service on 16 lines. 530 minibuses, under supervision of that company, are also responsible for passenger transport. all lines originate from one of these squares: Valiye-asr, 15-Khordad, Kamal-ol-molk, Darvaze-dolat. Therefore, this study evaluates the potential of these squares for future transit-oriented development, such as construction of station complexes around them. This evaluation will be conducted based on criteria related to land use, which was most important vriable according to expert opinions in previous section.

In oreder to feasibility study, at first, a circle was struck with the radius of 500 meters (the usual distance of walking) around four abovementioned squares in the ArcGIS software. Then, feasibility of TOD around these squares are investigated based on three land use criteria including population, land use type and population density of residential area in the affected zone.

ISBN 978-3-9504173-2-6 (CD), 978-3-9504173-3-3 (print)
Editors: Manfred SCHRENK, Vasily V. POPOVICH, Peter ZEILE, Pietro ELISEI, Clemens BEYER

6.1 Population

As more people live around an station, there has more potential to become a TOD center. In order to study the population criterion, blocks around stations Valiye-asr, 15-Khordad, Kamal-ol-molk and Darvaze-dolat, are shown in different colors according to their population. As it is clear in figure 3, Valiye-asr and 15-Khordad Squares have the greatest potential to convert to TOD centers, based on population criteria.

6.2 Density

The second criterion for examining the potential of stations, is the population density around four aforementioned squares, within the radius of 500 meters from them. Residential areas with high and medium density, have more potential to build the station complexes. For this purpose, blocks around these squares were classified into 4 categories based on the density, in terms of persons per hectare: low (less than 100), medium (101 to 200), high (201 to 300) and very high (301 and above) that has been shown by yellow, blue, green and purple colors respectively, in figure 4. As this figure shows, based on population density, Valiye-asr and 15-Khordad squares are more preferred than other squares.

6.3 Land use type

The third criterion to evaluate the feasibility of building station complexes around four above bus stations in the city of Kashan, is the type of land use. At first, land use has been divided into two categories: restrictive and provider. Utilities such as military, green space, educational, historical, cultural, urban facilities, and agriculture are restrictive. In contrast, commercial, residential and official utilities are among provider. Provider and restrictive utilities have been shown by arrangement with green and red colors in figure 5. By calculating the percentage of restrictive and provider areas within block of 500 meters radius around squares, results show that Kamal-ol-molk and 15-Khordad have greatest feasibility for TOD in future.

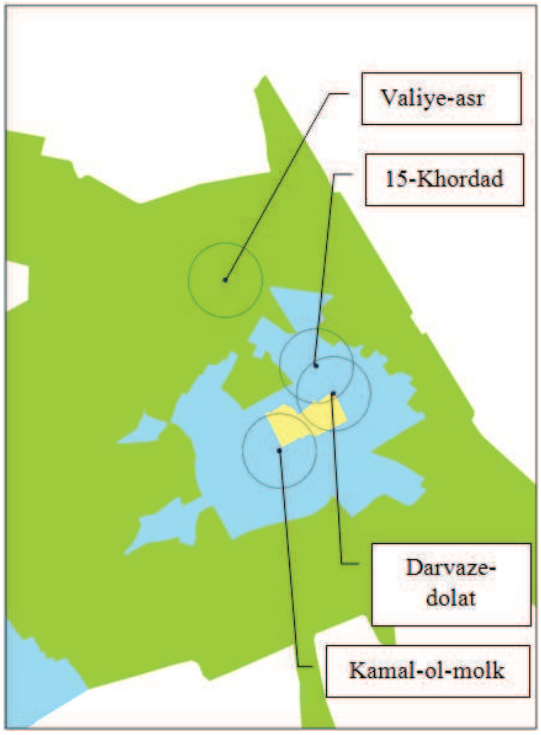


Fig. 3: Differences between four squares in Kashan city, based on population criterion (yellow: from 1005 to 1320 persons, blue: 1320 to 2000 persons, green: more than 2000 persons)

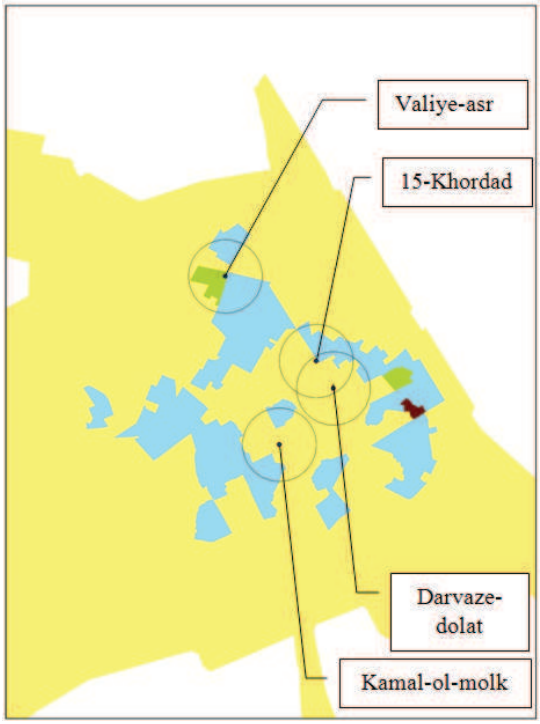


Fig. 4: Differences between four squares in Kashan city, based on density criterion (yellow: 5 to 100 (persons/ hectare), blue: 101 to 200 (persons/ hectare), green: 201 to 300 (persons/ hectare), purple: more than 300 (persons/ hectare))

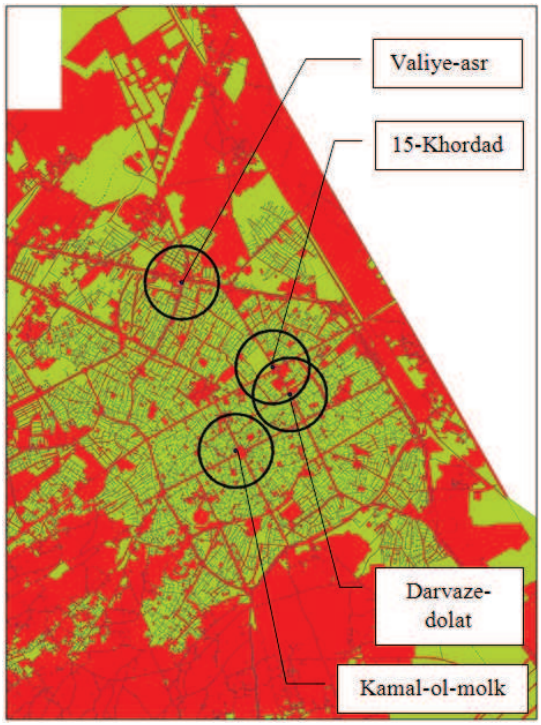


Fig. 5: Differences between four squares in Kashan, based on land use criterion (green: provider, red: restrictive)

7 CONCLUSION

The world is urbanizing and motorizing at an increasing speed. However, most developments around the world have taken place in an unsustainable manner, with priorities given to cars than public transit, walking and cycling. This development pattern has provoked problems that cities are facing today, such as tra¬ffic congestion and air pollution. Transit-oriented development (TOD), which promotes dense, mix-used urban development with good walking and cycling connections around transit stations, is a useful and important concept for future urbanism. Some principles and criteria have been proposed to achieve TOD-based urbanization. In this study, by interviewing with transportation planning experts and applying an AHP model, it was found that land use criteria are most important factors for transit-oriented development in

ISBN 978-3-9504173-2-6 (CD), 978-3-9504173-3-3 (print)
Editors: Manfred SCHRENK, Vasily V. POPOVICH, Peter ZEILE, Pietro ELISEI, Clemens BEYER

future. Population, density and land use type, either provider or restrictive, were considered as land use related criteria. Using ArcGIS software, information about these criteria were extracted from 500 meters radius blocks around four bus stations in main squares in Kashan, Iran. According to outputs, 15-Khordad square is one of the most feasible and potential bus stations for transit-oriented development and constructing a station complex around it. Indeed, due to the limited resources allocated to urban projects, it is necessary to determine most feasible and potential stations, especially with reference to land use factors, before any planning for TOD. Results show that land use parameters are key factors for detecting potential locations to achieve the sustainable development and mobility. It is suggested that more land use factors to be considered in future studies to obtain more reliable results.

8 REFERENCES

ALBERTI, M., & Waddell, P.: An integrated urban development and ecological simulation model. Integrated Assessment, 1(3), 215-227. 2000.

CALTHORPE, P.: The next American metropolis: Ecology, community, and the American dream: Princeton architectural press. 1993.

CRANE, R.: The influence of urban form on travel: an interpretive review. CPL bibliography, 15(1), 3-23. 2000.

CURTIS, C., Renne, J. L., & Bertolini, L.: Transit oriented development: making it happen: Ashgate Publishing, Ltd. 2009.

DIMITRIOU, H. T., & Gakenheimer, R.: Urban transport in the developing world: A handbook of policy and practice: Edward Elgar Publishing. 2011.

DODGSON, J., Spackman, M., Pearman, A., & Phillips, L.: Multi-criteria analysis: a manual. 2009.

HRELJA, R.: Integrating transport and land-use planning? How steering cultures in local authorities affect implementation of integrated public transport and land-use planning. Transportation Research Part A: Policy and Practice, 74, 1-13. 2015.

LITMAN, T.: Smart Growth Policy Reforms. Retrieved from www.vtpi.org/smart_growth_reforms.pdf. 2006.

MOUDON, A. V., & Stewart, O.: Tools for Estimating VMT Reductions from Built Environment Changes. Olympia, Washington: Washington State Department of Transportation. 2013.

PAULLEY, N., & Pedler, A.: TRANSLAND–Integration of Transport and Land Use Planning. Final Report of Transland, 2000, 169-182. 2000.

POULENEZ-DONOVAN, C. J., & Ulberg, C.: Seeing the trees and missing the forest: qualitative versus quantitative research findings in a model transportation demand management program evaluation. Transportation Research Record, 1-1. 1994.

RAMÍREZ, S. M., & Rosas, J. V.: Transit Oriented Development: Regenerate Mexican Cities to Improve Mobility. 2014.

SU, Q., & Zhou, L.: Parking management, financial subsidies to alternatives to drive alone and commute mode choices in Seattle. Regional Science and Urban Economics, 42(1), 88-97. 2012.