Computational Engineering and Physical Modeling 2-3 (2019) 53-64

Contents lists available at CEPM

Computational Engineering and Physical Modeling

Journal homepage: www.jcepm.com

Modelling Effects of Land Use Changes on Traffic Based on Proposed Traffic Simulator

M. Jabbari, S. Behzadi*

Department of Surveying Engineering, Faculty of Civil Engineering, Shahid Rajaee Teacher Training University, Lavizan, Tehran, Iran

Corresponding author: *behzadi.saeed@gmail.com*

https://doi.org/10.22115/CEPM.2020.207903.1073

ARTICLE INFO

Article history:
Received: 07 November 2019
Revised: 09 January 2020
Accepted: 20 January 2020

Keywords:
Land use change;
Traffic;
Traffic simulator;
Geospatial information systems.

ABSTRACT

In this paper, a traffic simulator is designed in order to investigate the travel demand based on GIS data and analysis. In order to evaluate the proposed simulator, four different scenarios are provided for the arrangement of land use services. In first scenario, all service land use are located in the middle of the region; in second scenario, land use services located on the periphery of the region; in the third scenario, land use is defined regularly in the entire area; and finally, in the last scenario, unchanged statuses are evaluated. The comparison parameters are Vehicle Miles of Travel (VMT) and Vehicle Hours of Travel (VHT), which are measured for these four scenarios. The analysis of the results shows that the regular distribution of land use service (scenario 3), with VHT, mean of 33.01 minutes is the best scenario, while scenario 2 with a VHT average of 35.12 minutes has the worst performance.

1. Introduction

Recently, one of the main problems in big cities is the unsuitable use of motor vehicles, especially private cars. This results in traffic congestion with side effects such as air and noise pollutions, which reduces the health and quality of citizen's life. The increase in the capacity

How to cite this article: Jabbari M, Behzadi S. Modelling Effects of Land Use Changes on Traffic Based on Proposed Traffic Simulator. Comput Eng Phys Model 2019;2(3):53–64. https://doi.org/10.22115/cepm.2020.207903.1073

of traffic networks has been proposed as a common solution to reduce traffic congestion, and its associated complications. Although this solution reduces the traffic load on a network unit level in a cross-sectional manner, it encourages the use of the network in the long-term[1]. Ease traffic flow is one of the preconditions for the townspeople. Fast and frequent local transportation in urban networks makes the city more sustainable and efficient. Due to the increased traffic volume, traffic congestion makes the life of citizens difficult in the city. In addition, increasing traffic congestion accelerates air pollution, which reduces the quality of life [2–4] In the last two decades, urban planning has been drawn to urban development patterns, which are able to reduce the volume of travel demand by bringing activities closer to each other. Land uses to determine the location of the activity; therefore, they determine the locations of travel destinations and destinations [5]. Traffic is basically is a function of land use [6,7]. There is a clear relationship between land use and traffic volume, so recognizing the effect of land user type on traffic production helps to manage road and highway networks more efficient [2,4]. However, unsustainable land use development exacerbates traffic congestion and increases air contamination. Hence, it is very important to integrate transport planning with land use planning decisions in order to have a habitable city [8]. Not only the improvement of land use patterns, but also the efficient location of activities effectively reduce the time trips, so the decision is mainly made based on the influences of socio-economic factors, and land use distribution conditions [9,10]. It is very important to understand the relationship between land use and transportation to design a safe and successful transport network. Effective use of land encourages urban activities and maintains roads and other transportation. Creating new roads and developing existing land uses to increase the attractiveness of the land. When cities grow slowly, land use and traffic planning are easily matching with each other. However, in the context of rapid economic growth, the demand for land use increases rapidly, but the development of transport facilities may not continue fast. Many cities with high economic growth experience heavy congestion and other transportation problems [11]. Unusual growth of traffic volume and its concentration are affected by the land use around roads. For example, increasing business activity in the vicinity of a road section can directly affect the traffic congestion of the morning rush hour [12–14]. On the other hand, the increase in residential units creates more traffic at the peak of the evening [15]. In addition, the growth of land uses may attract and generate traffic in large quantities. Roads, transit and other transport elements shape land development, while types and distribution of land use affect travel patterns and transportation facilities. The dispersal pattern of low-density development relies exclusively on vehicles as the primary mode of transportation. Alternatively, denser urban centers can combine different land uses adjacent to each other, and encourage various modes of transportation such as biking, public transportation, and so on [16]. Traffic patterns and congestion will be changed in response to changing land use in the future. Traffic data on traffic congestion include large scale information that is not readily available [17]. Hence, researchers consider traffic simulation as an important tool to represent the traffic and its effect on the environment.

Limited models of traffic congestion are presented to investigate the relationship between traffic density and urban land use. For example, Wingo Lowdon developed an economic model of how transport, urban land use, and location affect the way consumers go from their residence place to their workplace [18]. Alonso [19] improved a model by taking into account the values for land use in such a way that the amount of different urban designs is inverted with the cost of transport to the city center. Izraeli and McCarthy [20] found that the use of residential land had an impact on density; there was a positive correlation between population density and travel time. Handy [21] analyzed the effect of land use on traveler characteristics and found that the rate of travel repeatedly increased where land use density increased, and the travel distance increased to a level where travel speeds were reduced. Gordon et al. [22] analyzed satellite data from 82 US metropolitan areas in 1980 to extract information on the types of land uses (residential, industrial, and commercial). Considering the amount of employment, it was found that increasing industrial congestion reduces the travel time of cars as well as residential and commercial congestion. Ewing et al. [2,23] investigated the effect of the travel time and delay time of pedestrians using cross-country data from 83 metropolitan areas in the 1990s and 2000s. The results showed that travel time in the course of these two years was reversed with the combined land use index and directly related to street access.

So far, in most of the outlined researched, the issue of traffic has only been examined from the perspective of traffic engineers. For this reason, in many of these studies, traffic and network analysis have been used to solve traffic issue, while addressing other external factors such as land use is essential. The purpose of this study is to investigate the issue of traffic based on land use arrangement, and provide a suitable solution. In this research, attempt to examine the effects of land use on traffic. For this, a traffic simulator is designed that instantly tracks the area and displays it. In this simulator, the effects of land use changes on traffic are assessed. For this purpose, the effects of the different land-use layout are considered on traffic, and the best possible layout is obtained among four different scenarios. In the first scenario, all land use services are in the center of the area; in the second scenario, all of them are located around the area. In the third scenario, land use services are distributed throughout the region on a regular basis, and the fourth scenario is the current status of the area. For each scenario, the distance and period of time which each vehicle goes to its destination are examined. Finally, these scenarios are compared and the best one is determined.

2. Modeling the integration of land use and transportation

The integration of land use development with transportation planning has been recognized as an important aspect of smart growth and sustainable development [24,25]. In traffic theory, traffic flow modeling is used to indicate the volume, velocity and traffic density [26]. The results of transport demand are the spatial distribution of different land use patterns. Investigating the spatial relationship between land use and transportation is essential for transport policy and long-term planning. The prediction of land-use change is the first step in modeling the demand for transport because the future user creates social and economic data for transport models [27]. Based on the predictions of land use patterns, transport planners can simulate what steps should be taken to increase positive effects and prevent certain negative consequences. Therefore, land use prediction for transport planning is inevitable [28]. Land Use and Traffic Models (LUTI) focus on understanding travel behavior as a basis for forecasting and managing travel demand [29]. Figure 1 represents the the relationship between land use and transportation.

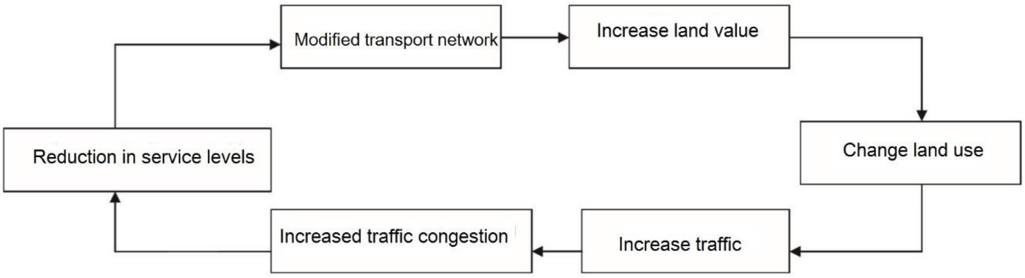

Fig. 1. The relationship between land use and transportation [30].

Land changes are related to the interactions among social, environmental and geophysical processes [31]. The consequences of land-use change can include losing biodiversity, climate change, increasing pollution, urban sprawl, and traffic. Demands for the industry and residential lands contribute to a lot of these changes, as well as transportation developments, which have changed vast areas of agricultural land along highways to residential and industrial land [32]. Selecting the right land, proximity to the transportation system is a major factor, especially in terms of local access and travel costs. Accidental land use development may increase travel demand, which is the result of a variety of spatial patterns of activities from different land use patterns. There is a complex relationship between land use and shipping, so it is important to know how land-use changes are affected by transport in order to have proper future planning and transport policies [28,33,34]. Planners and decision-makers can take necessary steps to plan for future growth with the simulation of future land use conditions. Figure 2 represents the relationship between land use planning and transportation.

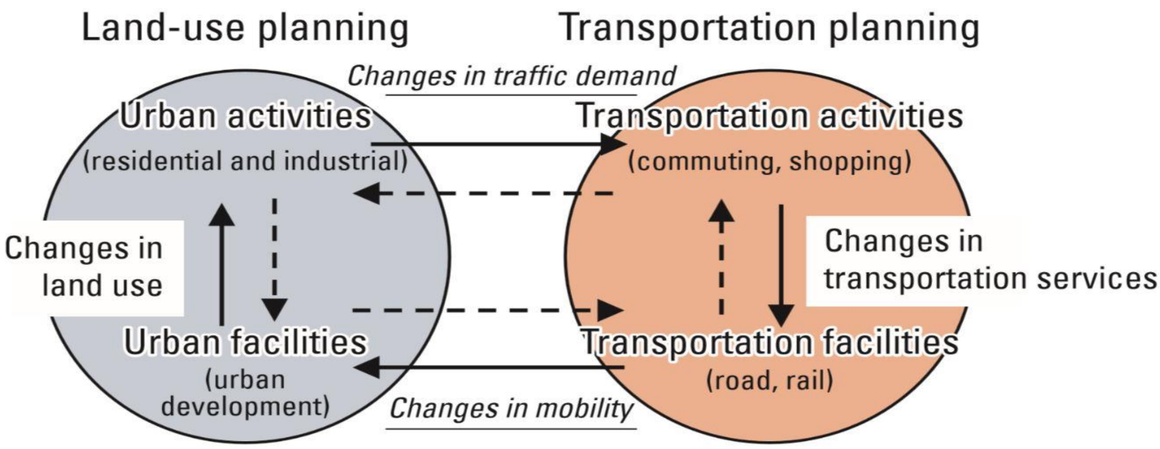

Fig. 2. The Relationship between Land Use Planning and Transportation [11].

3. Traffic simulation

Recently, mathematical simulation of transportation systems, mathematical modeling of transportation systems (such as freeway roads, arterial paths, metro fields, city center network systems, etc.) are done with the use of computer software to design and implement transport systems. The simulation of transportation systems has begun for more than forty years ago [35], and today is an important part of discipline in the planning of traffic engineering and transportation. National and local transportation agencies, academia, and consulting firms use simulation to help manage transportation networks. To model real scenarios, a spatial simulation requires data that describes the infrastructure as well as the actual traffic data. One of which with a sufficient quality can produce valid simulation results[36]. Simulation is important in transportation because it can study the complex analytical or numerical methods [37–39]. Traffic simulation models can be divided into macroscopic, mesoscopic, and microscopic models based on their level of detail [40,41]. The simulation designed in this research is a micro-simulator.

4. The study area and data used

Tehran, the capital of Iran, is the most densely populated city. With a population of more than 8.5 million, it is the 24th largest populated city in the world and the most populous city in western Asia. Tehran has ranked 132nd among the most polluted cities in the world from 146 countries [42]. More than two million vehicles per day in Tehran metropolitan area are considered critical, while Tehran's global position is fluctuating in comparison with other polluted cities between the first and second positions [43]. Tehran has suffered a severe deterioration in air quality due to the rapid growth of the population, the fleet of worn-out vehicles, a large number of industrial units, geographic and weather factors of the region. In some cases, high levels of pollutants forced authorities to shut down schools and impose traffic constraints [44]. The increase in population also raises problems with air pollution, noise pollution, and traffic congestion. Private car trips are common in Tehran, and citizens tend to use private cars. After the month of October, the traffic situation of the city is usually worse due to increasing student travel [45].

In this research, the data of streets and land use of Tehran region four have been used (Figure 3). Road and land use data are obtained from the Open Street Map (OSM) site for these areas. Next, the data is edited and all errors are deleted. The area consists of 4150 parcels, with 10 different types of users. The number of each land use is separated as shown in Figure. 4.

Fig. 3. Display the Tehran area 4 on the map of Google Map.

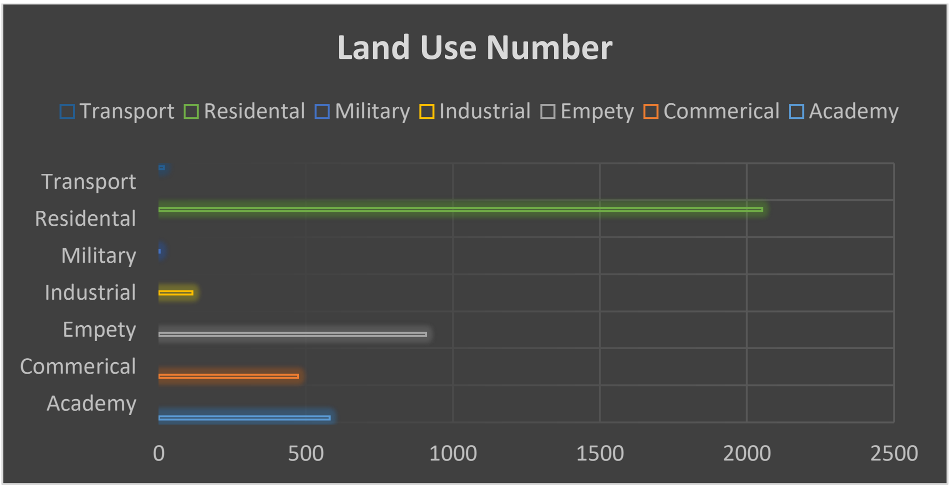

Fig. 4. Number of parcels per land use.

5. Methodology

To relieve the traffic congestion in cities, and to reduce energy consumption and transport emissions, people try to reduce vehicle travel with encouraging active travel (walking and cycling) and public transport. Besides traffic policies and management, land use policies are believed helpful to affect travel behavior. For example, recently, a mixed land use pattern has received researchers' attention[46]. Mixing land use could reduce vehicle use and encourage active travel [47]. The overall structure of the proposed methodology is seen in Figure 5.

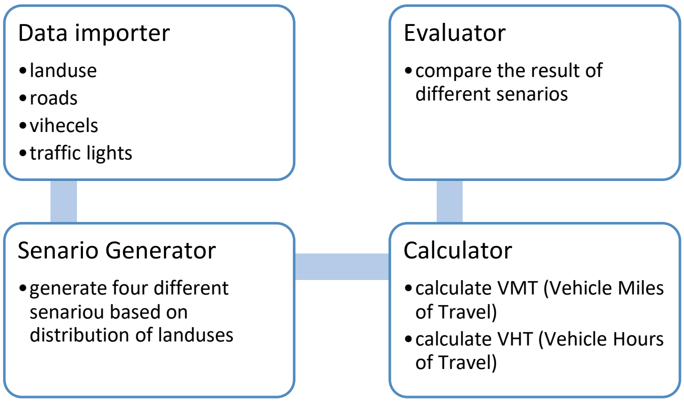

Fig. 5. Flowchart of the proposed methodology.

In this research, the land use services are examined in four different scenarios in the region, then the effects of each scenario are examined on VHT and VMT. The VMT (Vehicle Miles of Travel) travels as a combination of the vehicle number in the system and their distance. The VHT (Vehicle Hours of Travel) is calculated as the product of linkage and travel time of the link, aggregated on all links[48]. In Figure 6, each of the four scenarios is shown; the red parcels represent the land use of the service. In the first scenario, all land use services are aggregated in the center. In the second scenario, all of them are located around the area. In the third scenario, the use of services are distributed throughout the region in the form of multi-user land use; finally, the fourth scenario is the current status of the region that is being examined.

Fig. 6. Displays all scenarios and different service layout (Parcels with red color are land use service).

A traffic simulator is designed to examine the land use change in each scenario over traffic. This traffic simulator is a micro-simulator of traffic that uses GIS files (Shapefile). Like other micro-simulators, this simulator produces two kinds of results: animated display and numerical output in text files. In the animated display, the simulator displays the location of each vehicle in each time, and in the text files, the coordinates of each vehicle are specified at each time. This simulator has the ability to display the traffic volume of any street at any moment. It simulates the volume of streets in different hours of the day. In this simulator, most of the effort is done to examine the relationship between land use and traffic level in the city, so the amount of traffic is calculated based on changing the use of one or more parcels. This simulator has the ability to calculate how long a vehicle has traveled, and how far it has gone. The framing of the simulator motion animation is shown in Figure 7.

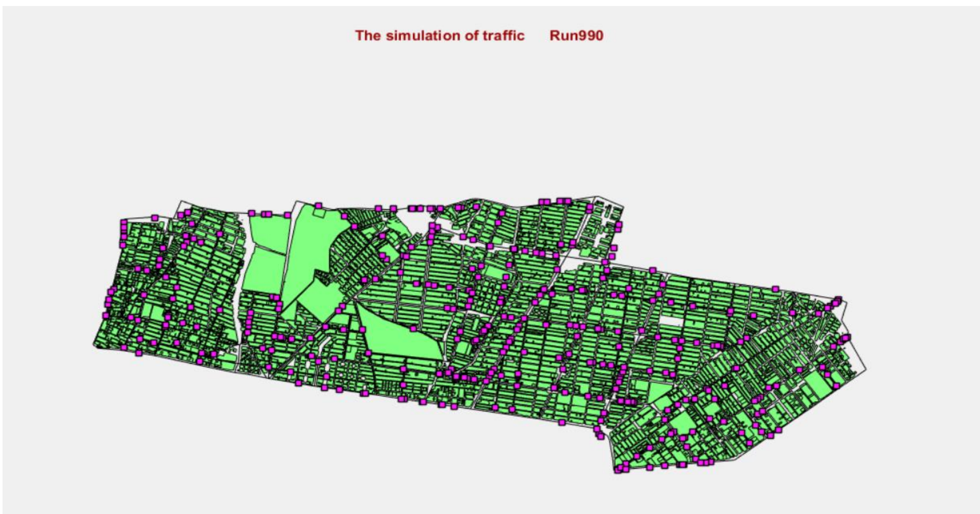

Fig. 7. Motion Detection of the GIS Traffic Simulator at 17:30 o'clock.

6. Results and discussion

The results of modelling the effects of land use on transportation can be very important in urban planning for land use planning in the transportation sector. In this study, a traffic simulator is designed using GIS analyses to investigate the effect of land use change (user service) on traffic in four different scenarios for Tehran Municipality District 4. To compare the quality of the scenarios, the parameters of VHT and VMT are calculated in each scenario. The output of these four scenarios is shown in Figure 8.

Due to the high number of vehicles, one-to-one comparisons are difficult and time-consuming, so the average VMT and VHT are calculated for each scenario; therefore, better comparison can be done among these scenarios to select the best one. As seen in Table 1, the results indicate that Scenario 3, in which service utilities are distributed regularly throughout the region, is the most appropriate arrangement, while scenario 2 has the worst ranking among the four scenarios. The notable point in Scenario 1 is that it has made the vehicles less distant, but did not make it faster, and this reflects the fact that the distance is not a good measure for the traffic performance of vehicles.

Table 1
The results of the mean VMT and VHT in each of the four scenarios.

scenario	mean VMT (km)	mean VHT (min)
1	2534.90	34.98
2	2687.86	35.12
3	2612.47	33.01
4	2667.21	34.88

Integration of land use development with transport planning is known as an important aspect of smart growth and sustainable development. The results of transport demand are affected by the spatial distribution of different land use patterns. Therefore, modelling and simulating traffic and the effects of land use changes on the traffic are very important for researchers. In this research, the best land use arrangement for land use services is investigated. For this purpose, a traffic simulator has been designed that examines and displays the traffic in the moment. In this simulator, the change in the use of each land affects traffic. Finally, the results of the work showed if the user's description of the service is carried out regularly in the entire region, it will create the best traffic situation; as a result, the vehicles will spend less time to reach the destination. This simulation will greatly help urban planners to predict and design sustainable urban development. Based on the simulation of future use conditions, planners and decision makers can take the necessary steps to plan for future growth.

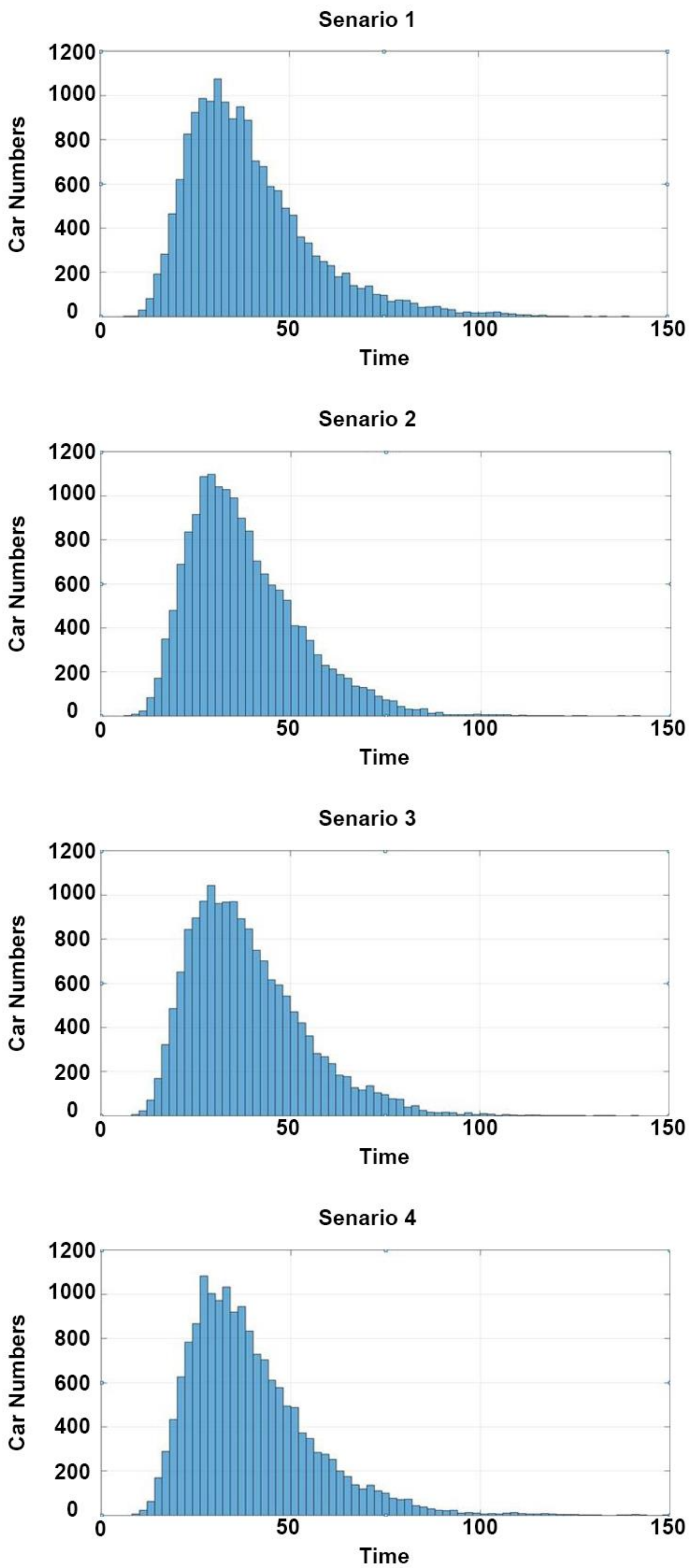

Fig. 8. The results of the simulator, the horizontal axis of travel time and the vertical axis of the number of cars for each scenario.

7. Conclusion

In this research, the authors investigate traffic in Tehran, the most populated city in Iran. The goal was to find the most suitable location for land use services in terms of traffic parameters.

For this purpose, traffic simulator is designed to examine the land use services in four different scenarios. The results obtained in each scenario are then compared with various parameters to select the most suitable arrangement. The results showed that the scenario in which land use services were located around the region would create the best traffic situation. This arrangement would allow for a shorter time to access these sites. In other words, accessing the results of this research can be very important for urban planners and land use planning, and can be a good guide to building a sustainable development.

References

[1] Behzadi S, Alesheikh AA. Introducing a novel model of belief–desire–intention agent for urban land use planning. Eng Appl Artif Intell 2013;26:2028–44. doi:10.1016/j.engappai.2013.06.015.

[2] Qi H, Wang W, Lu J. Study on the Relationship between Urban Land-Use and Traffic Generation with Remote Sensing and PLSR. ICCTP 2011, Reston, VA: American Society of Civil Engineers; 2011, p. 302–14. doi:10.1061/41186(421)32.

[3] D. S. Transportation for a Livable City. San Francisco CA; 2002, Retrieved July 2, 2013 n.d.

[4] Mousavi Z, Behzadi S. Geo-Portal Implementation with a Combined Approach of AHP and SWOT. Int J Nat Sci Res 2019;7:22–31.

[5] Guo Z, Agrawal AW, Dill J. Are Land Use Planning and Congestion Pricing Mutually Supportive? J Am Plan Assoc 2011;77:232–50. doi:10.1080/01944363.2011.592129.

[6] Mitchell RB, Rapkin C. Urban traffic: A function of land use. Columbia University Press; 1954.

[7] Behzadi S, Alesheikh AA. Cellular Automata vs. Object-Automata in Traffic Simulation. Int J Remote Sens Appl 2014;4:61. doi:10.14355/ijrsa.2014.0401.07.

[8] Litman T, Steele R. Land use impacts on transport. Victoria Transport Policy Institute Canada; 2017.

[9] Soltani A, Saghapoor T, Izadi H, Pakshir A. Trip generation and its relationship with land use diversity: Case studies of four urban districts in Shiraz metropolitan area 2012.

[10] Mousavi Z, Behzadi S. Introducing an Appropriate Geoportal Structure for Managing Wildlife Location Data. Int J Nat Sci Res 2019;7:32–48.

[11] Morimoto A. Transportation and land use in Doi, K. (ed.) Traffic and safety sciences: Interdisciplinary Wisdom of IATSS. 2015.

[12] Shubho MTH, Neema MN. Impact of land use change on prodigious traffic growth towards impeding livability of a city. Environ Ecol Manag 2014;2014:1–15.

[13] Arnott R, Inci E, Rowse J. Downtown Parking and Traffic Congestion: A Diagrammatic Exposition 2012.

[14] Council AT. National guidelines for transport system management in Australia. Backgr Mater 2006;5.

[15] Giuliano G. Land use impacts of transportation investments. Geogr Urban Transp 2004;3:237–73.

[16] Gehrke SR, Clifton KJ. An activity-related land use mix construct and its connection to pedestrian travel. Environ Plan B Urban Anal City Sci 2019;46:9–26.

[17] Zhang T, Sun L, Yao L, Rong J. Impact Analysis of Land Use on Traffic Congestion Using Real-Time Traffic and POI. J Adv Transp 2017;2017:1–8. doi:10.1155/2017/7164790.

[18] Wingo L. An economic model of the utilization of urban land for residential purposes. Pap Reg Sci Assoc 1961;7:191–205. doi:10.1007/BF01969080.

[19] Alonso W. Location and land use. toward a general theory of land rent. Locat L Use Towar a Gen Theory L Rent 1964.

[20] Izraeli O, McCarthy TR. Variations in travel distance, travel time and model choice among smsas. J Transp Econ Policy 1985:139–60.

[21] Handy S. How land use patterns affect travel patterns: A bibliography. 1992.

[22] Gordon P, Kumar A, Richardson HW. Congestion, Changing Metropolitan Structure, and City Size in the United States. Int Reg Sci Rev 1989;12:45–56. doi:10.1177/016001768901200103.

[23] Ewing R, Pendall R, Chen D. Measuring Sprawl and Its Transportation Impacts. Transp Res Rec J Transp Res Board 2003;1831:175–83. doi:10.3141/1831-20.

[24] Wachs M. Transportation Policy, Poverty, and Sustainability. Transp Res Rec J Transp Res Board 2010;2163:5–12. doi:10.3141/2163-01.

[25] Quade PB, Douglas. Douglas. Land Use Impacts of Transportation A Guidebook_Integration of Land Use Planning with Multimodal Transportation Planning. 1998 1998:127–46.

[26] Tseng F-H, Hsueh J-H, Tseng C-W, Yang Y-T, Chao H-C, Chou L-D. Congestion prediction with big data for real-time highway traffic. IEEE Access 2018;6:57311–23.

[27] Waddell P. UrbanSim: Modeling Urban Development for Land Use, Transportation, and Environmental Planning. J Am Plan Assoc 2002;68:297–314. doi:10.1080/01944360208976274.

[28] Peng Z-R, Zhao L-Y, Yang F. Development of a prototype land use model for statewide transportation planning activities. 2011.

[29] Acheampong RA, Silva EA. Land use–transport interaction modeling: A review of the literature and future research directions. J Transp Land Use 2015;8:11–38.

[30] Stults M. Integrating climate change into hazard mitigation planning: Opportunities and examples in practice. Clim Risk Manag 2017;17:21–34. doi:10.1016/j.crm.2017.06.004.

[31] Kim JH, Hipp JR, Basolo V, Dillon HS. Land Use Change Dynamics in Southern California: Does Geographic Elasticity Matter? J Plan Educ Res 2018;38:39–53. doi:10.1177/0739456X16688252.

[32] Babiso B, Toma S, Bajigo A. Land use/land cover dynamics and its implication on sustainable land management in Wallecha watershed, southern Ethiopia. Glob J Sci Front Res H Environ Earth Sci 2016;16:49–53.

[33] Waddell P, Borning A, Noth M, Freier N, Becke M, Ulfarsson G. Microsimulation of urban development and location choices: Design and implementation of UrbanSim. Networks Spat Econ 2003;3:43–67.

[34] Miller E. The case for microsimulation frameworks for integrated urban models. J Transp Land Use 2018;11:1025–37.

[35] Pursula M. Simulation of traffic systems-an overview. J Geogr Inf Decis Anal 1999;3:1–8.

[36] Bieker L, Krajzewicz D, Morra A, Michelacci C, Cartolano F. Traffic Simulation for All: A Real World Traffic Scenario from the City of Bologna, 2015, p. 47–60. doi:10.1007/978-3-319-15024-6_4.

[37] Lemos LL, Bazzan ALC. Combining adaptation at supply and demand levels in microscopic traffic simulation: a multiagent learning approach. Transp Res Procedia 2019;37:465–72. doi:10.1016/j.trpro.2018.12.217.

[38] Sokolowski JA, Banks CM. Principles of modeling and simulation: a multidisciplinary approach. John Wiley & Sons; 2011.

[39] Hunter M, Biswas A, Chilukuri B, Guin A, Fujimoto R, Guensler R, et al. Energy-Aware

Dynamic Data-Driven Distributed Traffic Simulation for Energy and Emissions Reduction. Handb. Dyn. Data Driven Appl. Syst., Cham: Springer International Publishing; 2018, p. 467–87. doi:10.1007/978-3-319-95504-9_20.

[40] Li D, Cova TJ, Dennison PE. Setting Wildfire Evacuation Triggers by Coupling Fire and Traffic Simulation Models: A Spatiotemporal GIS Approach. Fire Technol 2019;55:617–42. doi:10.1007/s10694-018-0771-6.

[41] Amarasinghe UGLS, Rajapakse RACP. Swarm intelligence for urban traffic simulation: Results from an Agent-based modeling and simulation study of the Sri Lankan context. International Research Conference on Smart Computing and Systems Engineering-SCSE 2018.

[42] The population of Tehran is derived from the website: http://worldpopulationreview.com/world-cities/tehran-population/ n.d.

[43] Mohammadiha A, Malakooti H, Esfahanian V. Development of reduction scenarios for criteria air pollutants emission in Tehran Traffic Sector, Iran. Sci Total Environ 2018;622–623:17–28. doi:10.1016/j.scitotenv.2017.11.312.

[44] Moradi A, Soori H, Kavousi A, Eshghabadi F, Jamshidi E, Zeini S. Spatial analysis to identify high risk areas for traffic crashes resulting in death of pedestrians in Tehran. Med J Islam Repub Iran 2016;30:450.

[45] Heger M, Sarraf M. Air Pollution in Tehran. World Bank; 2018. doi:10.1596/29909.

[46] Kantor Y, Rietveld P, van Ommeren J. Towards a general theory of mixed zones: The role of congestion. J Urban Econ 2014;83:50–8. doi:10.1016/j.jue.2014.08.003.

[47] Lyu X, Han Q, Vries B de. Validation of a simulation system exploring land-use impacts on travel behavior. Transp Res Procedia 2019;37:51–8. doi:10.1016/j.trpro.2018.12.165.

[48] Reisi M, Aye L, Rajabifard A, Ngo T. Land-use planning: Implications for transport sustainability. Land Use Policy 2016;50:252–61. doi:10.1016/j.landusepol.2015.09.018.