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Exploring an Interaction Model for Land Used Intensity-traffic Congestion

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Abstract

Traffic flow is a result of the connection between the derived demand and land use. The derived demand varies in space and time, this study explores how traffic congestion is correlated with land use patterns. Historically, statistical models were used to predict and analyze these patterns. The methodology of this study is to investigate this interaction by statistical methods such as linear regression modeling. This analysis was performed using various land use types that could influence the demand. From the regression analysis, the best influence variables that affect the model are land use variables. The strong statistical parameter is commercial land use, which affects traffic volume, and causes the highest traffic congestion. In addition, correlation values are negative, meaning that as commercial land use increases, traffic flow increases and road capacity decreases. When modeling with the commercial land use variable, we conclude the value of R-Squared = 0.87 and that the relationship is an inverse strong relationship between traffic volumes and commercial land use. Mostly, land use govern traffic demand.

Keywords

land use, traffic congestion, shopping centers

1 Introduction

Traffic congestion is a recent urban issue that increases day over day, most transportation planners and decision-makers try to investigate factors that affect this issue (Abdullah and Asmael 2023; Mohanty et al., 2023; Samal et al., 2022). Most planners attempt to construct good transportation systems capable to integrate and accommodate the mobility of people and goods. The relationship between traffic volume and land use is often studied in the context of urban planning and transportation management. Travel movement is related to the magnitude of activities and land use type. Ibad et al., 2022 stated that there is a strong correlation between traffic volume and the area of land use that affects traffic movement. Urban areas with higher population densities and mixed-use developments (residential, commercial, and recreational activities) tend to have more complex traffic patterns and higher traffic volumes. This is because mixed-use areas attract various activities, leading to more trips being generated throughout the day. While other stated that the appropriate share of land use types in urban planning can indeed help decrease congestion time and ensure the efficient operation of traffic movement Zhang et al., 2017. Kanyepe et al., 2021 stated that the relationship between traffic and land use is less addressed in developing countries. The importance of a correlation between the two is not understood, and the lack of methodological approaches for measuring the relationship between the two is still unclear. Many scholars investigate this issue and try to understand the relationship between land use and traffic demand. Lopa et al., 2022 studied the influence of land-use change in the Tallasa City corridor on traffic generation in Makassar City. The methodology started by characterizing existing transportation movement and its relation with land use, examining land use development and its effect on trip generation. They concluded that land-use change decreases the level of road services in the future. Aldiansyah, 2022 stated that the creation of the Tajur Transmart Mall in East Bogor District in 2019 would develop a considerable point of attraction movement that proves a need for improvement of road infrastructure, and enhance mass public

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transport system to increase road efficiency in the future. Zhang et al., 2017 discovered the correlation between land use and traffic congestion by observing the real traffic congestion points for the Fourth Ring Road in Beijing, China, the results showed that the impact of the high percentage of commercial land use remarkably influences the congestion time. Bao et al., 2022 inspect the temporal spatial analysis of traffic congestion. They investigate a small city, Xining, in China. Residential and educational land use were found to contribute significantly to congestion and their mixed effects tend to worsen the status. Davarnia and Gursoy 2021 stated that the implication of land use data, demographic and socio-economic, could be represented as significant factors to predict accurate analysis for traffic changes. Wadud and Chen 2018 investigate the impact of shopping centers and related roadside frictions on congestion in Dhaka. The density of shopping centers leads to bottlenecks on the roads. Results show that the speed difference was more noticeable in these areas. On weekdays, when shopping centers were closed, the average speed grew up to 18.5%. Moses et al., (2021). Stated that the commercial land use development leads to expanding the generated traffic by 200 Passenger Car Units (PCU) on Bharathi Road during the evening peak period 4.30 p.m to 6.30 p.m. Kuzmyak, 2012 used volume over capacity (V/C ratio) as a measure in the United States of America and found less congestion despite more densities in four Phoenix transportation corridors. Yap et al., 2022 investigate the type of land use that affects traffic congestion in Kuala Lumpur. The data were collected by questionnaires and analyzed by statistical analysis. The findings showed that the highest level of traffic congestion is because of a high commercial land use proportion. They recommended to implement a grid plan and mixed land use to decrease delays in Kuala Lumpur.

The study of traffic impact Analysis (TIA) is used to assess whether the new development is proper and if any transportation improvements would be needed. Urban planners are greatly concerned about the necessity of implementing TIA for new development, Regidor and Teodoro (2005). The United Republic of Tanzania (2008) introduced Urban Planning Guidelines to state measures when a TIA study has to be employed. There is a necessity for TIA for residential or non-residential developments when they double the existing traffic volume, like for areas, the site has to generate 250 vehicles in the peak hour.

TIA has not been adequately considered during the implementation of land use change in Iraq; all projects lack implementing a traffic impact study for the existing road network. Land use changes normally take place at individual plots or buildings without taking into account TIA requirement. Land use types developed around roads affect unusual growth of traffic volume Ahmed et al., (2011). Investigating the spatial relationship between land use and traffic congestion is a key step for controlling demand distribution and a policy toward long-term planning. There is a clear relationship between land use and traffic volume, so recognizing the effect of land use type on traffic generation helps to manage road and highway networks more efficiently.

2 Study area

Isolated planning of land use without considering its relation with transportation systems can lead to increased congestion. Big shopping centers develop high-attraction travel demand. In recent years, many mall sites were constructed without analyzing the traffic impacts from the changing land use on the existing road network. In Iraq, TIA is the most neglected element in urban planning, this study revealed how this affects congestion. The study area is located in Baghdad city; four shopping malls as shown in Fig. 1 located on major roads were selected to study the effect of shopping centers on traffic demand and to evaluate nearby road service levels. The study aims to predict travel attraction occurrence in existing conditions that occur due to the existence of different land uses. The traffic pattern was explored by conducting a road traffic survey during the period between 8 p.m. to 9 p.m. at the following selected roads:

1. Rowad street
2. 14 Ramadan street
3. Rubaie street
4. Damascus street.

A buffer was fixed around the mall location to 2 km to classify each land use. Each area was classified according to specific land use. For a catchment area with a diameter of 2 km around the malls, eight classes of land use types were found to estimate the intensity of each land use.

Fig. 1 Study area

3 Data aggregation

The primary data collection includes two phases, the first phase collects land use data by interviewing building owners. This process continues from one land use to another to classify each land use and estimate the percentage of each type of land use. Arc GIS is applied to measure the area of each land use type inside the catchment area of each mall. The summary of land use classification is shown in Fig. 2. The second phase included the roadside survey to collect the number of vehicles and speed on four road sections. The camera was located near the roadside and set in a good location to show the street clearly. Traffic flow was observed from 8.00 to 9.00 pm on weekend days because this period fell into the peak period as stated by Al-Tamimi and Asmael, 2021; Asmael and Turky 2021; Asmael and Kadhim 2020. The volume of traffic was extracted manually as shown in Fig. 3. Other secondary data as shown in Table 1 include the number of lanes, the existence of on-street parking, and the existence of near intersections within buffer areas; these variables were included in statistical modeling and other variables as shown in Table 2.

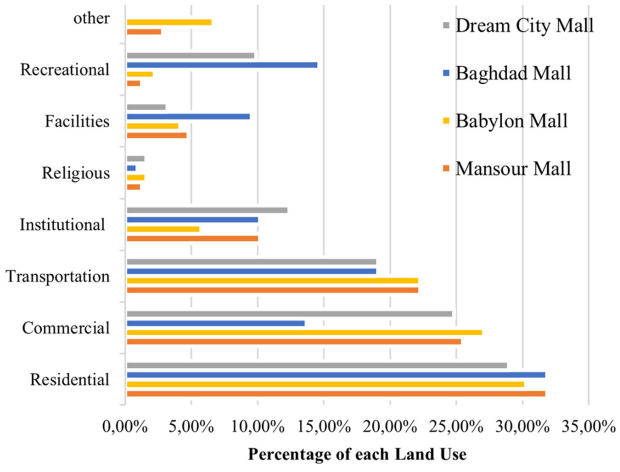

Fig. 2 Land use distribution around four selected sites

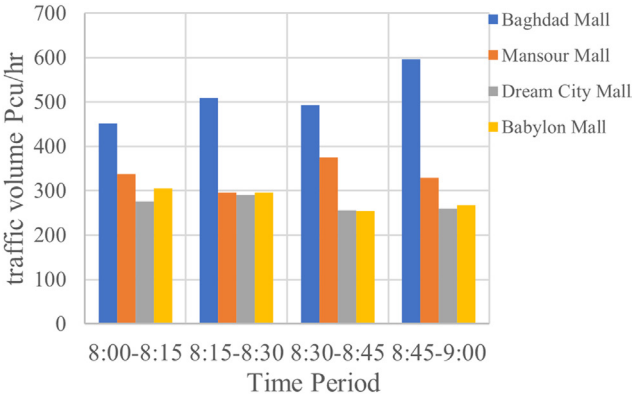

Fig. 3 Traffic volume near selected sites

Table 1 Characteristics of the selected site's

location	No. of lane	Parking	No. of Intersection
Baghdad mall	3	No	1
Mansour mall	2	Yes	2
Dream city mall	3	No	1
Babylon mall	2	Yes	1

Table 2 Variables used in Regression analysis

Independent Variable	Description
No.intersection (NI)	Number of intersections around site
Parking (P)	Existence of Parking around sites
No. of lane (NL)	Number of lanes of nearby roads
Institutional (I)	Percentage of Institutional land use around the site
Transportation (T)	Percentage of Transportation land use around the site
Commercial (C)	Percentage of Commercial land use around the site
Residential (R)	Percentage of Residential land use around the site

4 Analysis and discussion

All the data collected were sorted to be ready to use in SPSS, the sample points included in the analysis were 50. Regression analysis explains the relationship between the dependent and independent variables. The dependent variable was traffic volumes (y) in 15 minutes and the independent variables were the percentage of each type of land use. Other independent variables were also investigated like the number of lanes, number of intersections, and existence of parking. Land use variable that affected the volume of traffic was used through regression analysis and simple and multiple models were generated. The correlation relationship between various variables is shown in Table 3. It is obvious that there is a negative relation between traffic volume and commercial land use; commercial land use decreases the road capacity and speed of traffic.

The statistical modeling states the size of the influence variables on the dependent variable. There are four major types of land use variables in this analysis. A linear regression analysis was performed between the traffic volume and the percentage ratio of four types of land use. Building a regression model was performed in the SPSS program developed by IBM® Developer. The generated model shows the relationship between the variables. The results showed that the reasonable ratio of commercial land use type could efficiently decrease road capacity and increase congestion time. The results of the modeling are seen in Table 4 below.

Table 3 The correlation table

	No. Intersection	*Parking*	*No. of lane*	*Institutional*	*Transportation*	*Commercial*	*Residential*	*Traffic volume*
No.intersection	1							
Parking	0.57735	1						
No. of lane	–0.57735	–1	1					
Insitiutional	0.13245	–0.6882	0.68824	1				
Transportation	0.57735	1	–1	–0.68825	1			
Commercial	0.33028	0.6674	–0.6674	–0.26249	0.667424	1		
Residential	0.55555	0.1924	0.19245	–0.04415	0.19245	–0.51378	1	
Traffic volume	–0.14028	–0.3490	0.34903	0.002223	–0.34903	–0.89328	0.695078	1

Table 4 The Interaction-Developed Models

Model 1							
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*F*	*Significance F*	*R Square*
Intercept	145.7083	83.30561	1.749082	0.086947	6.381331	0.015038	0.12
No. of lane	82.54167	32.67515	2.52613	0.015039			
Model 2							
Intercept	393.3333	23.10481	17.02386	1.74576E–21	6.381331	0.015038	0.12
Parking	–82.5416	32.6751	–2.5261	0.01503			
Model 3							
Intercept	–168.111	191.384	–0.878398	0.384393	155.6417	6.05174E–21	0.87
Commercial	–16.42509	1.392402	–11.79622	2.29983E–15			
Residential	29.20166	5.620944	5.195152	4.79061E–06			
Model 4							
Intercept	1238.136	76.07477	16.27525	3.09045E–20	144.9792	7.958E–23	0.90
No. Intersection	–1.78030	15.34505	–0.116018	0.908166			
No. of lane	–106.3939	16.84407	–6.316399	1.15564E–07			
Commercial	–26.8636	1.389276	–19.33642	3.91948E–23			

When modeling the road properties variable with the dependent variable, it appeared that the value of *R*-Squared = 0.12. The greater the number of lanes, the higher the traffic numbers, and the greater the capacity of the road. In addition, the relationship is an inverse weak relationship between traffic volumes and the existence of parking. The modeling of the traffic volume with road properties appears to explain only 12%.

After entering the data of land use and traffic volumes in the regression model, it is noticed that the results of the value of *R*-Squared = 0.87 and this means that the relationship is directly strong between the data variables, which means the effect of land use on traffic volumes is large, this is agreed with Ibad et al., 2022.

After that, the model between Commercial land uses, number of lanes, number of intersections, and the traffic volumes were generated. The *R*-Squared improved to 0.9. The relationship is strongly negative between traffic volumes and commercial land use, meaning that the greater the commercial land use, the lesser the traffic volumes.

Overall, after analyzing the data, the change in land use can have both positive and negative impacts on traffic volumes in an area. Understanding the potential impacts of land use changes on traffic can help inform land use planning and transportation decision-making to minimize negative impacts and promote more sustainable and efficient use of transportation resources. In addition, the number of lanes, intersections, and parking have an impact on traffic flow, so the site must be studied before establishing any commercial or residential developments.

The study area was stressed with evening traffic volume on weekends and only the morning peak showed better mobility. Table 5 shows the difference between morning and evening road service level. Weekend congestion is significantly worse which implies stronger management measures to alleviate traffic congestion during this time.

Table 5 The effect of commercial land use on road service level

location	Speed in the Morning period (Km/hr)	Speed in the Evening Period (Km/hr)	Delay in the Evening Period (min.)
Baghdad mall	60	35	3
Mansour mall	40	20	13
Dream city mall	50	30	5
Babylon mall	40	15	12

It appears that a Traffic Impact Study (TIS) is a necessary step to conduct before establishing any commercial or residential developments because Land Use planning decisions create more congested urban areas and thus create changing travel patterns, which have an impact on traffic-related risks to society as a whole.

5 Conclusions

Based on the results of the study, it can be concluded that the interaction between traffic demand and land use is significantly high. Commercial land-use intensity (size and scale of activity) affects traffic movement and represents the major influence on congestion. This indicates that the development of commercial activities directly affects the development of travel movements in the area. Therefore, the local authority must apply TIA for any new development before creating a decision to change the land use. How the trips generated are distributed across the road network surrounding the mall should be analyzed, taking into account access points, available roads, and existing transport infrastructure. This analysis helps to identify potential areas of congestion or traffic flow disruptions. Therefore, a traffic impact study is a necessary step before the creation of any new land use. The current traffic situation in the area surrounding the mall, including traffic volumes, congestion levels, and rush hour traffic patterns was analyzed. The road beside Baghdad Mall has a higher capacity than other locations. The other variables related to road characteristics showed a minor effect on congestion. Problems associated with the selected locations may be solved by changing entrance points to the mall, improving intersection geometry, implementing traffic signal improvements, providing additional turning lanes, creating new access points, or promoting alternative modes of transportation such as public transport or cycling walking facilities. Evaluation of different scenarios or alternative designs for mall development to identify options that reduce the effects of traffic. This may include looking at different access configurations, parking layouts, or staging strategies.

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