

# Navigating Campus Traffic: Analysing the Impact of Land Use on Congestion at King Abdulaziz University, Jeddah, Saudi Arabia

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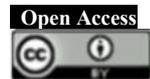
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## Abstract

The present research examines the correlation between land use and traffic congestion at King Abdulaziz University in Jeddah, Saudi Arabia. The authors analyze the Congestion Index Value (CIV) data and land use proportions to determine the main factors that contribute to congestion. Additionally, the authors examine how different land use arrangements affect traffic flow on the campus. The analysis employs both Ordinary Least Squares (OLS) and Geographically Weighted Regression (GWR) models to consider spatial variability. The findings demonstrate that specific purposes, such as hospitals, housing, areas designated for females, and central administrative structures, have a substantial impact on traffic flow. Furthermore, the presence of educational structures and their closeness to different entrances on campus are crucial determinants of congestion levels. The research indicates that strategically locating facilities and optimizing infrastructure near important entrances can reduce congestion and improve movement on campus. These insights offer essential direction to urban planners and university administrators in formulating efficient traffic management and sustainable urban development policies.

**Keywords:** Traffic Congestion, Land Use, Congestion Index Value (CIV), OLS, GWR, King Abdulaziz University

## 1. Introduction

The problem of traffic congestion has become widespread in urban places across the globe, greatly affecting the overall quality of life, economic output, and environmental sustainability (Aljoufie, 2014). The effects of this matter are extensive and diverse. It significantly affects the quality of life for city residents as a whole (Mac Domhnaill et al., 2022). Increased travel periods and unreliable transport, for instance, can contribute to anxiety and a reduction in leisure time. On the other hand, a carefully organized spatial configuration of various land purposes, in which residences, workplaces, and facilities are situated nearby, can decrease travel distances and requirements (Ye et al., 2022). The arrangements of land use can also impact the effectiveness of transportation networks. A city with a compact and mixed-use development can support more efficient public transportation and non-motorized modes of travel, such as walking and cycling (Hendrigan & Newman, 2017). Conversely, a city that is spread out with different types of land uses might result in a greater reliance on personal vehicles, which in turn contributes to increased traffic congestion (Gao & Zhu, 2022). Land use is a critical determinant of traffic

congestion because the spatial arrangement of diverse land functions can have an impact on both travel demand and the efficiency of transportation systems (Alipour & Dia, 2023).

Rapid urbanization and economic growth in Jeddah, the second-largest city in Saudi Arabia, have resulted in a rise in automobile ownership and subsequent traffic issues (Ministry of Municipal and Rural Affairs, 2019). Jeddah, like other expanding urban regions, encounters difficulties concerning sustainable urban mobility and planning. King Abdulaziz University (KAU), situated in the metropolitan landscape of Jeddah, offers a compelling opportunity to investigate these matters owing to its expansive campus, the substantial daily influx of people, and the consequent traffic dynamics. In the context of educational institutions, such as King Abdulaziz University in Jeddah, Saudi Arabia, understanding the relationship between land use and traffic congestion is crucial. These institutions often host a large number of students, staff, and visitors, leading to high travel demand and potential congestion, especially during peak hours (El-Quliti & Abed, 2013). This paper aims to explore the

relationship between land use and traffic congestion at King Abdulaziz University. The authors aim to acquire insights into the contribution of different land uses to traffic congestion and explore new techniques for congestion reduction by analyzing the relationship between Congestion Index Value (CIV) and land proportion.

## 2. Literature Reviews

The influence of land use on urban traffic congestion has been a topic of extensive research and discussion in the field of urban planning and transportation. Early studies by researchers such as (Cervero, 1996) have highlighted the role of land use patterns in shaping traffic conditions. Cervero's work, in particular, has emphasized that higher densities, mixed-use developments, and pedestrian-friendly areas tend to experience lower levels of congestion. This is primarily because these areas encourage walking, cycling, and the use of public transportation, thereby reducing the reliance on private vehicles. Similarly, (Ewing, 1997) has contributed significantly to this body of knowledge. His research corroborates Cervero's findings, further reinforcing the idea that well-planned urban environments can effectively mitigate traffic congestion. Ewing's work also introduces the concept of 'urban sprawl' and its impact on traffic conditions, providing a comprehensive understanding of how urban form influences travel behavior.

However, the relationship between land use and traffic congestion is complex and multifaceted. The previous study points out that there are discrepancies in how these factors interplay at different scales and in different urban contexts (Handy, 2005). For instance, while higher densities might reduce congestion at a neighborhood level, they could potentially increase congestion at a city-wide level due to the concentration of activities and destinations. Similarly, the effectiveness of mixed-use developments in reducing congestion might vary depending on factors such as the availability of public transportation and the design of the street network.

Despite the valuable insights provided by these studies, gaps remain in the existing literature. Most notably, there is a need for more recent data and the application of advanced statistical methods to account for the multifaceted nature of the relationship between land use and traffic congestion. This study seeks to address these gaps by providing a comprehensive analysis of the influence of land use on urban traffic congestion, using recent data and advanced statistical methods. The findings of this study will not only contribute to the existing body of knowledge but also inform urban planning policies and practices aimed at reducing traffic congestion. Recent research has started to focus on addressing these knowledge gaps. An investigation conducted Bao et al. (2022) examined the spatial-temporal distribution of traffic congestion in Xining, a small-scale city in China. The study revealed that the presence of educational land use and residential areas in Xining has a substantial

impact on traffic congestion, and when these factors are combined, they worsen the situation. This work enhances comprehension of traffic congestion in small metropolitan areas, offering urban planners and policy-makers novel perspectives to develop data-driven approaches for alleviating traffic congestion.

Zhang et al. (2017) conducted a study that utilized real-time traffic and point of interest (POI) data to examine how land use affects traffic congestion. The study revealed that the substantial prevalence of commercial land utilization has a considerable impact on traffic congestion. The study also indicated that a well-balanced distribution of land use types could effectively decrease congestion time. This study aims to expand on the aforementioned recent discoveries by conducting a thorough examination of the impact of land use on urban traffic congestion. It will utilize up-to-date data and employ sophisticated statistical techniques. The results of this study will not only add to the current knowledge but also provide guidance for urban planning policies and practices that aim to decrease traffic congestion.

## 3. Methodology

### 3.1 Study Area

King Abdulaziz institution, a private national institution, was founded in 1967 and is named after the founder of Saudi Arabia (Al-Filali et al., 2023). King Abdulaziz University (KAU) is located in the south district of Jeddah, Saudi Arabia, and is a prominent educational and research institution in the area (Fig.1). The university campus spans a considerable expanse and encompasses a wide range of land uses (6 Km<sup>2</sup>), such as academic buildings, administrative facilities, residential spaces for students and teachers, recreational amenities, and huge parking lots (M. Ali & M. Jamalallail, 2023). The campus is strategically located near key urban roads, which significantly impacts the flow of incoming and outgoing automobile traffic. The institution accommodates around 117,000 students and faculty members, 24 faculties, whose everyday travel greatly adds to the traffic congestion in the nearby regions (Al-Filali et al., 2023).

The campus design features many entry and exit points (7 gates) that are intimately linked to the primary transportation infrastructure of the city. Distinct zones within the university include the academic location, where most of the faculties and lecture halls are located, the residential zones with student dormitories and faculty housing, commercial zones with shops and eateries, and the administrative area that houses essential university management buildings. The diversity in land utilisation on the campus offers a miniature representation of metropolitan traffic movement and congestion problems, rendering it an exceptional subject for examining the influence of land utilisation on traffic congestion.

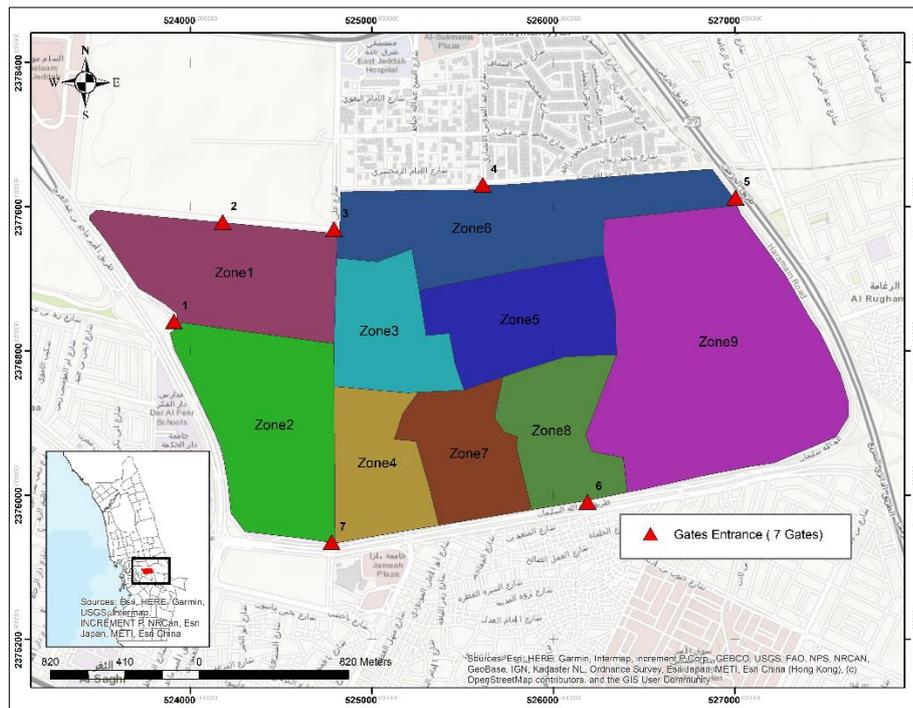


Fig. 1. Map of the study area

The campus occupies a vast expanse and the authors partitioned it into nine distinct zones, each marked by specific land utilization patterns that aid in the examination of traffic movement and congestion. Each of these zones has been designed carefully with distinct functional goals, which have a direct impact on the everyday flow of automobiles and pedestrians. The study utilizes the zonal division to carefully examine the impact of various land use areas inside the campus on overall traffic congestion. It specifically focuses on analyzing the variations in the Congestion Index Value (CIV) across these zones.

### 3.2 Data Collection

The data on traffic congestion were obtained from a field study conducted at King Abdulaziz University. Google Maps Survey obtained precise data on three key metrics: time (measured in minutes), velocity (measured in kilometers per hour), and distance (measured in km), using a combination of manual surveys and automatic traffic recording devices. These data were gathered for each of the nine specified zones and the primary entrances to the campus. Data were collected at various intervals (15-60 minutes) throughout the day (07.00 a.m. until 03.00 p.m.) for each zone and entry to capture fluctuations in traffic flow according to usual campus activities, including peak hours, and off-peak hours. The data that was gathered was subsequently utilised to compute the Congestion Index Value (CIV) for every zone and entrance. The CIV offers a numerical assessment of the amount of traffic and disruptions in the flow, which is crucial for evaluating the degree of congestion in various regions of the campus.

This data is used to analyse the Congestion Index Value for each zone and entrance. The land use data were obtained from the official departments of King Abdulaziz University and GIS databases. The

university's planning and infrastructure departments supplied comprehensive maps and data on the existing land usage within the campus boundaries. The land was classified as educational buildings, administrative buildings, special use, and educational purposes. The authors employ regression analysis to investigate the correlation between congestion and land use by utilizing independent and dependent variables derived from CIV data and land use data (Table 1).

Table 1. Parameters and Sources.

Variables	Parameters	Types of Data	Sources
Dependent Variable	Congestion Index Value (CIV)	Scale Data/ Number	Calculated from field surveyed Data
Independent Variable (47 sample points)	Female Zone	Nominal Data/ Value Label 0= No 1= Yes	Survey and interpretation of satellite imagery.
	Special Uses (Hospitals, Housings, Female Zone, Central Administrative Building)	Nominal Data/ Value Label 0= No 1= Yes	Survey and interpretation of satellite imagery.
	Education Buildings	Nominal Data/ Value Label 0= No 1= Yes	Survey and interpretation of satellite imagery.
	Distance to Gate 1	Scale Data/ Number	Calculated from GIS data

	Distance to Gate 2	Scale Data/ Number	Calculated from GIS data
	Distance to Gate 3	Scale Data/ Number	Calculated from GIS data
	Distance to Gate 4	Scale Data/ Number	Calculated from GIS data
	Distance to Gate 5	Scale Data/ Number	Calculated from GIS data
	Distance to Gate 6	Scale Data/ Number	Calculated from GIS data

	Distance to Gate 7	Scale Data/ Number	Calculated from GIS data
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The study utilised both global/ OLS and spatially weighted regression models to examine the spatial variability of the correlation between land use and traffic congestion. In order to ensure a strong basis for these analyses, the researchers chose to use a minimum sample size of 30 observations. The determination of this sample size was based on initial testing that indicated it was adequate to establish statistical significance while also keeping the computational workload acceptable.

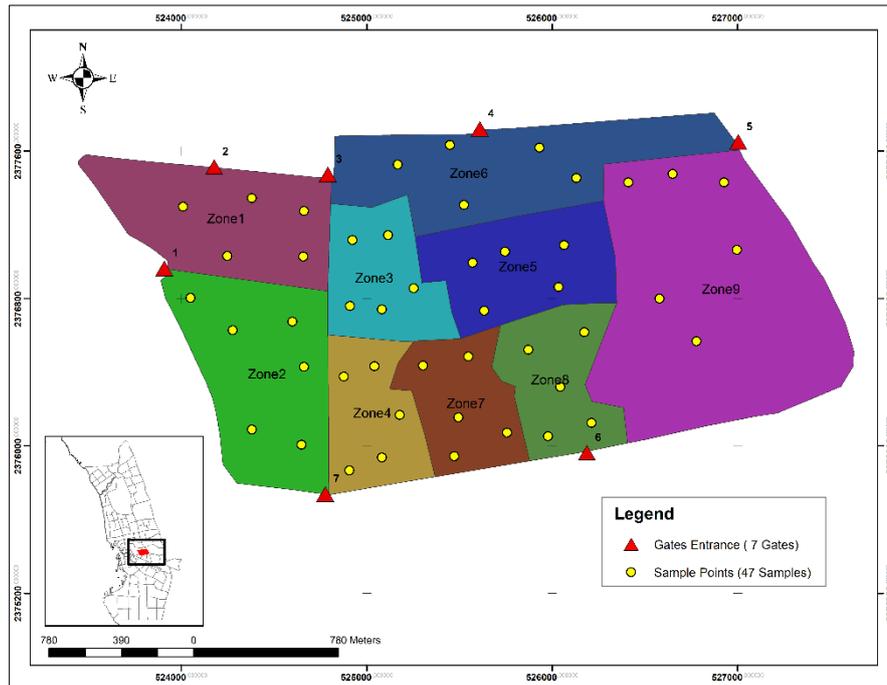


Fig. 2. Map of Sampling Points Distribution

Point observation (Fig.2) refers to a distinct combination of variables gathered from various zones inside the campus of King Abdulaziz University. The chosen sample size not only guarantees the dependability of the regression findings but also offers a complete representation of the various land use patterns and their effect on congestion throughout the research region.

### 3.3 Congestion Index Analysis (CIV)

To compute the congestion index based on time, speed, and length data, it is advisable to consult the study conducted by Taylor in 1992, titled Exploring the Nature of urban traffic congestion: concepts, parameters, theories, and Models (Taylor, 1992). This study presents a thorough comprehension of the characteristics of traffic congestion and formulates parametric explanations for the different degrees of congestion in an urban road network. As stated by Taylor (1992), the main indicators and the formula of congestion index (CI) are as follows:

$$CI = \frac{c - c_0}{c_0} \quad (1)$$

Where;

$C$  : represents the travel conditions (time, speed, or distance) during peak hours.

$C_0$  : represents the travel conditions (time, speed, or distance) during off-peak hours.

The variable  $c$  represents the overall duration of the trip, while  $c_0$  represents the time it takes to travel without any congestion or delays (free flow time). Free flow travel time refers to the duration required to go a certain distance under conditions of minimal traffic density. Travel time refers to the overall duration of a journey, encompassing the time taken from the start to the finish. The average speed of the journey can be determined by dividing the total distance by the time taken to cover that distance. According to Taylor (1992) states that a congestion index close to 0 signifies extremely low levels of congestion. Conversely, a congestion index close to 1 typically indicates crowded situations.

To analyze traffic congestion, the study employed a meticulous data collection process focused on travel surveys. These surveys gathered detailed information on travel times, speeds, and distances across different zones of the campus. Data were collected

during both off-peak and peak hours to capture a comprehensive view of traffic dynamics.

Off-Peak Hour Observations:

- Periods: 06:00 - 07:30 and 15:00 - 17:00
- Parameters Recorded: Travel times (in minutes), speeds (in kilometers per hour), and distances (in kilometers)
- These periods were chosen to reflect typical non-peak traffic conditions, providing a baseline for comparison against peak hour data.

Peak Hour Observations:

- Periods: 07:30 - 10:00 and 13:00 - 15:00
- Parameters Recorded: Similar to off-peak observations, with a focus on travel times, speeds, and distances
- Peak hours were selected based on the university's activity schedule, capturing the busiest times when students and faculty commute to and from classes and other activities.

### 3.4 Land Use Proportion Calculation

A comprehensive spatial analysis was conducted to determine the land proportions on the King Abdulaziz University campus. This analysis aimed to quantify the extent and distribution of various land uses in relation to the overall area of the campus. The land use categories were digitized and mapped using GIS software to generate an accurate geographical representation of the campus. A distinct layer was allocated to each land use category in the GIS, enabling advanced spatial analysis and visualization. The proportion of each land type was computed by measuring the area (in square kilometers or hectares) of each land use category and afterward dividing it by the total campus area. The formula employed is as follows:

$$\text{Land Proportion} = \left( \frac{\text{Area of Specific Land Use}}{\text{Total Campus Area}} \right) \times 100\% \quad (2)$$

A percentage was calculated for each land use category to determine its share in relation to the overall campus. The percentages were essential for evaluating the influence of particular land use categories on traffic congestion.

### 3.5 Global Regression Analysis (OLS) and Geographically Weighted Regression (GWR)

The calculated land proportions were subsequently incorporated into the wider traffic study. The research might investigate statistical linkages and patterns by analyzing the proportions in relation to the Congestion Index Value (CIV) data received from traffic surveys. The integration was accomplished by employing regression analysis, with land proportions serving as independent variables that influenced the dependent variable, CIV. In the OLS model, the relationship between the dependent and independent variables can be described by a linear equation, where the values of  $y$  (CIV) are estimated based on the values of  $x$  (independent variables). The global regression model can be presented using Eq. (3).

$$Y = \beta_0 + \sum_{j=1}^p \beta_j x_j + \varepsilon \quad (3)$$

the dependent variable is represented by  $Y$ , the model's intercept is denoted as  $\beta_0$ ,  $X_j$  represents the  $j$  explanatory variable in the model (where  $j$  ranges from 1 to  $p$ ), and  $\varepsilon$  represents the random error.

GWR is a statistical method that utilizes the non-parametric locally weighted regression approach for curve-fitting and smoothing applications, while local regression parameters are computed by employing subsets of data that are near a model estimation point in the variable space (Gilbert & Chakraborty, 2011)

$$Y_i = \beta_{i0} + \sum_1^p \beta_{ik} x_{ik} + \varepsilon_i \quad (4)$$

The variables  $\beta_{ik}$  and  $X_{ik}$  represent the factors and observed values of the independent variable  $k$  (where  $k$  ranges from 1 to  $p$ ) for observation  $i$ . The term  $\varepsilon_i$  refers to the error term for observation  $i$  (Isazade et al., 2023).

## 4. Results and Discussions

This section provides the results of the thorough examination of traffic congestion and land usage at King Abdulaziz University. The study analyses the geographical distribution of the Congestion Index Value (CIV) across nine specific zones on the campus using data obtained from field surveys and Geographic Information System (GIS) databases. Through the integration of CIV data with detailed land use classifications, the authors aim to elucidate the relationship between various land use types and traffic congestion levels.

### 4.1 Congestion Index Analysis

The travel survey was conducted on Sunday, December 3, 2023, a weekday, from 07:00 to 15:00, with data collected at intervals ranging from 15 to 60 minutes. The authors calculated the average travel time, speed, and journey length for each zone and entrance (Table 2).

Table 2 displays the Congestion Index Raw Data for King Abdulaziz University, providing specific information on the average travel times, speeds, and route durations in various zones during both off-peak and peak hours. During peak hours, there is an evident increase in the average travel time across all zones, which suggests a higher level of congestion. The data obtained from the travel surveys, which includes average travel times, speeds, and route lengths, will be used to compute the congestion index value (CIV) for each zone inside King Abdulaziz University. The CIV quantifies traffic congestion, providing insights into the traffic flow management and experiences of different zones.

**Table 2.** Surveyed Travel Data.

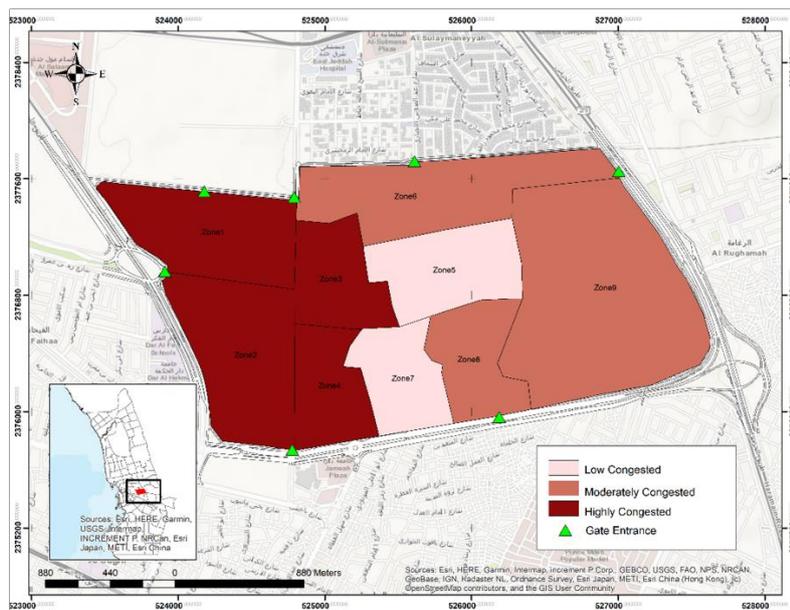
Zones	Off-Peak Hours 06.00-07.30 and 15.00-17.00			Peak Hours 07.30-10.00 and 13.00-15.00		
	Average Time/T <sub>0</sub> (Minute)	Average Speed/S <sub>0</sub> (Km/h)	Average Length/L <sub>0</sub> (Km)	Average Time/T (Minute)	Average Speed/S (Km/h)	Average Length/L (Km)
Zone 1	6	31	3.21	9	22	3.21
Zone 2	8	26	3.61	11	20	3.61
Zone 3	5	31	2.41	6	22	2.41
Zone 4	6	25	2.16	8	18	2.16
Zone 5	6	24	2.11	6	23	2.11
Zone 6	5	30	2.13	5	26	2.13
Zone 7	6	26	2.64	6	26	2.64
Zone 8	6	28	2.70	7	23	2.70
Zone 9	4	29	2.51	6	25	2.51

**Table 3.** Congestion Index Value (CIV).

Zones	Congestion Index			Category
	C <sub>0</sub> = L <sub>0</sub> / S <sub>0</sub>	C = L/ S	CIV= (C-C <sub>0</sub> )/ C <sub>0</sub>	
Zone 1	0.10	0.15	0.48	48% increase in travel time during peak hours compared to off-peak hours
Zone 2	0.12	0.17	0.41	41% increase in travel time during peak hours compared to off-peak hours
Zone 3	0.07	0.10	0.37	37% increase in travel time during peak hours compared to off-peak hours
Zone 4	0.08	0.11	0.31	31% increase in travel time during peak hours compared to off-peak hours
Zone 5	0.08	0.09	0.05	5% increase in travel time during peak hours compared to off-peak hours
Zone 6	0.07	0.08	0.17	17% increase in travel time during peak hours compared to off-peak hours
Zone 7	0.10	0.10	0.01	1% increase in travel time during peak hours compared to off-peak hours
Zone 8	0.09	0.11	0.25	25% increase in travel time during peak hours compared to off-peak hours
Zone 9	0.08	0.09	0.14	14% increase in travel time during peak hours compared to off-peak hours

The calculated CIV values will offer a comprehensive comprehension of congestion levels across various zones. Greater congestion is indicated by higher CIV values, which point to areas that need specific actions. Through the comparison of CIV

values in different zones, the research will uncover congestion patterns in relation to land use types, providing valuable insights into the influence of various land use configurations on traffic flow.



**Fig. 3.** CIV Map

The map (Fig.3) illustrates the Congestion Index Value (CIV) across King Abdulaziz University's campus, highlighting three levels of congestion: low, moderate, and high. Zones 1, 2, 3, and 4 experience the highest congestion, likely due to their proximity to main entrances and significant buildings. Zones 6, 8, and 9 show moderate congestion, while zones 5 and 7 have the lowest congestion levels. This pattern suggests that areas near major access points and key facilities face more traffic.

#### 4.2 Land Proportion

The land percentage study offers a comprehensive examination of the spatial arrangement of different land use categories inside the campus of King Abdulaziz University. This analysis tries to determine the impact of various land use configurations on traffic congestion by quantifying the area occupied by each land use category and estimating their proportions relative to the overall campus area. The findings from this research will be combined with the Congestion Index Value (CIV) data to clarify the connection between land use and traffic flow patterns around the campus.

Table 4 presents the proportions of different land use categories within each zone of King Abdulaziz University's campus. Zone 4 and Zone 5 are predominantly academic, with 47.88% and 47.91% of their areas dedicated to educational buildings, respectively. In contrast, zone 9 and 6 have no

educational buildings but zone 9 contains the highest proportion of university housing at 58.39%. Other zones with significant university housing include zone 8 (19.00%) and zone 6 (8.09%). Administrative buildings are most concentrated in zone 3, which allocates 36.83% of its area to administrative functions, whereas zone 9 lacks administrative facilities entirely. Parking areas are most prominent in zone 5, covering 40.20% of its area, indicating a need for substantial vehicular accommodation, while zones 7 and 9 have relatively low proportions of parking areas at 6.53% and 0.90%, respectively.

Special-use land is significantly present in zone 1, occupying 37.82% of the area (central hospital), suggesting varied activities that could affect traffic patterns. Conversely, zone 9 has no special use land, but this zone is special use for housing only. Vacant land and open spaces are most prevalent in zone 9, which dedicates 33.29% of its area to these uses, potentially influencing future development plans. Meanwhile, zone 3 has the least vacant land at 3.69%. Lastly, infrastructure is highly concentrated in zone 6, covering 25.72% of its area, reflecting robust support facilities, while zone 1 allocates 5.67% to infrastructure. This comprehensive breakdown of land use proportions across the zones offers valuable insights into campus utilization and its impact on traffic congestion.

**Table 4.** Land Proportion (%), King Abdulaziz University.

Land Use (%)	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9
Education Building	14.93	36.99	16.25	47.88	47.91	0	35.94	33.31	0
University's Housing	0	8.09	0	0	0	0	19.00	0	58.39
Administrative Building	9.82	6.14	36.83	10.96	1.49	16.76	9.29	5.77	0
Parking Areas	14.09	8.15	20.63	19.80	40.20	20.35	6.53	30.20	0.90
Special Use	37.82	13.76	1.40	0.93	0	18.28	3.78	6.55	0
Vacant Land/ Open space	17.66	15.26	3.69	10.06	5.81	18.90	9.81	7.42	33.29
Infrastructure	5.67	11.61	21.19	10.38	4.59	25.72	15.64	16.74	7.42

The concentration of high congestion in Zones 1, 2, 3, and 4 indicates these areas are likely crucial for campus activities, due to containing main academic buildings, hospital center, administrative offices, or other high-demand facilities. Their proximity to main entrances (gates 1,2,3) underscores their role as primary access points.

#### 4.3 Analytical Integration (Regression Analysis)

In this section, the authors integrate the land use data with the Congestion Index Value (CIV) analysis to explore the relationship between various land use types and traffic congestion levels within King Abdulaziz University's campus. By correlating the calculated land proportions with the CIV data, we aim to identify significant predictors of congestion and quantify the impact of different land use configurations on traffic flow. This analytical integration provides a comprehensive understanding of how spatial distribution and land use intensity influence congestion patterns, offering valuable insights for targeted interventions and strategic planning to enhance campus mobility. In Table 5, the

authors employ CIV as the dependent variable and include ten independent variables.

**Table 5.** Global Regression and GWR Analysis.

No.	Parameters	p-values (OLS)	R <sup>2</sup> GWR
1.	Female Zone	0.212	0.485
2.	Special Uses (Hospitals, Housings, Female Zone, Central Administrative Building)	0.001*	0.553
3.	Education Buildings	0.261	0.527
4.	Distance to Gate 1	0.000*	0.681
5.	Distance to Gate 2	0.000*	0.621
6.	Distance to Gate 3	0.000*	0.533
7.	Distance to Gate 4	0.044	0.510
8.	Distance to Gate 5	0.000*	0.624
9.	Distance to Gate 6	0.000*	0.605
10.	Distance to Gate 7	0.039	0.482

Residual sum of square	0.326	
AICc	-66.939	
Adj. R <sup>2</sup>	0.700	
Log-likelihood	50.057	

\*Significant p-value ( $p < 0.01$ )

The  $p$ -value is used in hypothesis testing to support or reject the null hypothesis. It represents the probability that the results of the test occurred at random. If the  $p$ -value is less than 0.01 (1%), it is statistically significant and can reject the null hypothesis. Conversely, a  $p$ -value higher than 0.01 is not statistically significant and indicates strong evidence for the null hypothesis. This means that the variable is not significant. In this research, the  $p$ -value of the female zone is 0.212 suggesting that the variable is not statistically significant at the global level. It indicates that the female area is not exclusively a factor that influences traffic congestion at KAU. At the local level (GWR), an  $R$ -squared of 0.485 means a significant relationship with congestion because 48.5% of the variability in the outcome data can be explained by the model. Furthermore, in the OLS model, several factors have a significant impact on congestion at KAU. These parameters include special uses and the distance to gates 1, 2, 3, 5, and 6. Conversely, the remaining parameters (education buildings, gate 4, and gate 7) are not significant, as indicated by their  $p$ -values being greater than 0.01.

On average, all parameters in the GWR model exhibit higher  $R^2$  values ( $>0.4$ ), indicating that spatial variability plays a crucial role in predicting and managing campus traffic. For example, the distances to different gates have a substantial impact on congestion, and they have a strong ability to explain congestion in the GWR model. Gate 1 has the highest  $R^2$  GWR value of 0.681, indicating that it is the most influential gate in terms of congestion.

Overall, the model shows a strong correlation, with an adjusted  $R^2$  of 0.70, suggesting that 70% of the variation in congestion can be accounted for by the chosen parameters. The Akaike Information Criterion (AICc) and Log-Likelihood values further support the model's adequacy in capturing the relationship between land use, gate distances, and congestion. These findings indicate that careful planning for designated areas for certain purposes, educational facilities, and entrance control can successfully alleviate traffic congestion and enhance movement inside the campus.

## 5. Conclusions

This study offers a thorough examination of the connection between land use and traffic congestion at King Abdulaziz University. It utilizes data on Congestion Index Value (CIV) and land use proportions to identify important factors that contribute to congestion. The results of our study indicate that certain types of facilities, such as hospitals, housing areas, designated female zones, and central administrative buildings, have a significant influence on traffic patterns. This effect is particularly pronounced in both the OLS and GWR models. The location and management of educational buildings and the distances to different gates are important factors in determining congestion levels. The adjusted  $R^2$  value of 0.700 highlights the

strength of our analytical approach, suggesting that 70% of the variation in traffic congestion can be accounted for by the chosen parameters. The significant association observed indicates that geographical heterogeneity and land use intensity play a crucial role in anticipating and managing traffic flow on the campus.

### 5.1 Implications For Urban Transport Planning

The findings obtained from this study are highly beneficial for urban planners and university administrators. By strategically arranging the placement of special use areas and educational facilities, it is possible to greatly reduce traffic congestion. One way to reduce congestion hotspots is by decentralising administrative processes and establishing various hubs for specific purposes (Afrin & Yodo, 2020), which can uniformly distribute traffic. In addition, enhancing the infrastructure surrounding important entrances, specifically Gates 1, 2, 3, 5, and 6, can optimise the movement of vehicles and alleviate congestion points.

Implementing specific traffic management measures, such as scheduling classes and administrative tasks at different times, can also help reduce congestion during peak hours (OECD, 2007; Musa et al., 2023). Promoting the adoption of alternate transport modes, such as cycling and walking, particularly in very congested areas, can further diminish dependence on private vehicles and enhance overall mobility (Agaton et al., 2020; Chondrogianni et al., 2023).

The integration of land use and traffic data provides an effective tool for comprehending and tackling traffic congestion at King Abdulaziz University. The results of the study not only add to the current knowledge but also offer practical insights for campus planners and urban developers. By implementing targeted measures informed by these findings, King Abdulaziz University can optimise campus mobility, increase the quality of life for its community, and make a valuable contribution to the overarching objective of sustainable urban development in Jeddah. The approaches and insights obtained from the current research can also be used as a blueprint for other educational institutions and metropolitan regions grappling with comparable difficulties, fostering more effective and sustainable traffic management strategies on a worldwide scale.

### 5.2 Recommendations For Future Research

Although this study offers valuable insights into the correlation between land use and traffic congestion, more research is required to investigate additional variables and their effects. Subsequent research endeavours may integrate up-to-the-minute traffic information, account for seasonal fluctuations, and examine the influence of particular occurrences on levels of congestion. Furthermore, conducting an analysis of the efficacy of adopted interventions over a period of time would offer significant insights for ongoing enhancement in traffic management methods.

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