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DEVELOPING THE CITY AND SUSTAINABLE DEVELOPMENT: URBAN SUBURBAN AREA OF HERTASNING - TUN ABDUL RAZAK METROPOLITAN MAMMINASATA, INDONESIA

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Abstract

The development of peripheral areas as centres of socio-economic activity has an impact on land use change and the complexity of the transport system. The ongoing spatial transformation contributes to anthropogenic enhancement towards urban macroclimate change. Increased anthropogenic activity is characterised by changes in typology, land use and traffic performance along the corridor. This study examines the relationship between traffic and land use performance variables and climatic conditions using a quantitative approach. The data that has been processed is then analysed using SEM PLS. The results of the analysis show that land use variables affect climate conditions with a T-Statistic value of 2.752 > 1.96 or a P value of 0.040 < 0.05. These results suggest that land use in the Hertasning-Tun Abdul Razak road corridor is positively associated with increased urban temperatures. This study recommends the handling of urban fringe areas towards controlling spatial utilisation along major road corridors, in anticipation of increasing urban macroclimate change.

Keywords: Land Use, Traffic Performance, Climate Change

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INTRODUCTION

Excessive urbanisation in the dynamics of urban development has an impact on changes in the characteristics and typology of peripheral areas. This condition is characterised by changes in land use that develop as new settlement areas. Furthermore, the increase in development activities not only impacts the emergence of new activities but also contributes to the urban macroclimate (Liu, Z. et al., 2019; Aguilar et al., 2022; Sahana et al., 2023). Urbanisation is positively associated with the expansion of urban areas into peripheral areas and impacts land use change and transport system complexity towards environmental degradation (Dadashpoor et al., 2019; Othman & Ali, 2020; Surya et al., 2021). Furthermore, changes in the temperature profile of urban areas are characterised by increases in rainfall intensity, relative humidity, and solar radiation patterns (Morris et al., 2017; Pyrgou et al., 2019; Li et al., 2022). Thus, the effects of urbanisation not only contribute to urban sprawl but also to the complexity of transport systems, requiring comprehensive and integrated planning mechanisms towards sustainable development (Lara et al., 2021; Rasoolimanesh et al., 2022). The integration of urban systems will encourage the stability of spatial utilisation, ecosystem restoration, and the creation of community social cohesion. This means that the quality of planning and spatial utilisation of peripheral areas as a unified system will have an impact on social, economic, and environmental sustainability (Abid et al., 2019; Chatterjee et al., 2022). Furthermore, the development of urban areas will require consideration of land use effectiveness and efficiency, appropriate zoning practices, and transport systems that integrate towards sustainable development that requires collaborative support between the public sector, government, communities, and the private sector (Solly, 2021; Acierto et al., 2023; Alipour & Dia, 2023).

The Hertasning-Tun Abdul Razak suburb is an area that experiences intense development of socio-economic activities, resulting in changes in urban microclimate characteristics. These changes are more likely to result from increased population mobility based on the origin and destination of movement and its impact on the transport system and land use along the Hertasning-Tun Abdul Razak road corridor. The intensity of built-up areas that tends to increase over time contributes to the availability of land for green open areas, thus affecting the condition of natural vegetation and its effect on global warming. These conditions are characterised by climate change, weather anomalies, and their effects on urban flooding (Rushayati et al., 2016; Huang et al., 2020; Arshad et al., 2022).

The trend of spatial utilisation patterns in the Hertasning-Tun Abdul Razak periphery area is in line with the intensity of large-scale residential development and infrastructure development support has an impact on the connectivity of the Mamminasata Metropolitan urban transport system.

Furthermore, the development orientation of the Hertasning-Tun Abdul Razak periphery will require spatial utilisation control and land use regulation in areas that must be protected towards the management and arrangement of urban transport systems (Kii et al., 2019; Surya et al., 2021). Environmental degradation of peripheral areas is characterised by a decline in air quality and its effects on public health. Three factors have led to the decline in air quality, including: (1) conversion of productive agricultural land; (2) increased population mobility; and (3) increased urban activity or change in status of rural areas towards urban areas (Yunus, 2008; Xu et al., 2016; Piracha at al., 2022).

The Hertasning-Tun Abdul Razak area was originally productive agricultural land characterised by traditional settlement patterns (houses on stilts), later developments were characterised by the emergence of modern architectural types of residential buildings developed by housing developers. Furthermore, the spatial dynamics of the Hertasning - Tun Abdul Razak periphery were developed to fulfil the need for residential facilities integrated with infrastructure development (D'Acci, 2019; Ouedraogo et al., 2023). Agricultural land use change characterised by residential and commercial development is the driving force of land use change supported by high population density and its impact on the growth of the Hertaning-Tun Abdul Razak suburb. The land use of the peripheral area in 2023 occupies an area of 1,146.66 ha, consisting of: parking area zone of 0.54 ha, education facilities of 1.00 ha, worship facilities of 0.26, office and commercial facilities of 1.69 ha, residential area of 95.60 ha, road median of 0.03 ha, lake of 1.85 ha, road of 37.79 ha, road green belt of 1.71 ha, pond of 20. 79 ha, field of 55.34 ha, mixed land of 93.51 ha, cemetery of 5.23 ha, grassland of 9.85 ha, yard of 208.34 ha, plantation of 36.84 ha, swamp of 7.40 ha, paddy field of 302.62 ha, shrub of 88.96 ha, river of 10.02 ha, and park of 10.62 ha. Thus, spatial utilisation in these peripheral areas is an urban area that requires management and control towards sustainability and the creation of a balance between space and carrying capacity and population capacity (Singh, 2020; Abera, et al., 2023). Furthermore, the Hertasning-Tun Abdul Razak periphery area requires treatment and strategies to support the integration of urban systems towards sustainable development (Barros, et al., 2018; Nickayin, et al., 2020). Thus, industrial activities and urban transport systems contribute to changes in the visibility and atmospheric absorption of solar radiation, which are determinant factors in the climate characteristics of urban areas (Barreto et al., 2017; Song et al., 2020; Perez & Pereira, 2023). The Hertasning-Tun Abdul Razak suburb is presented in Figure 1 below.

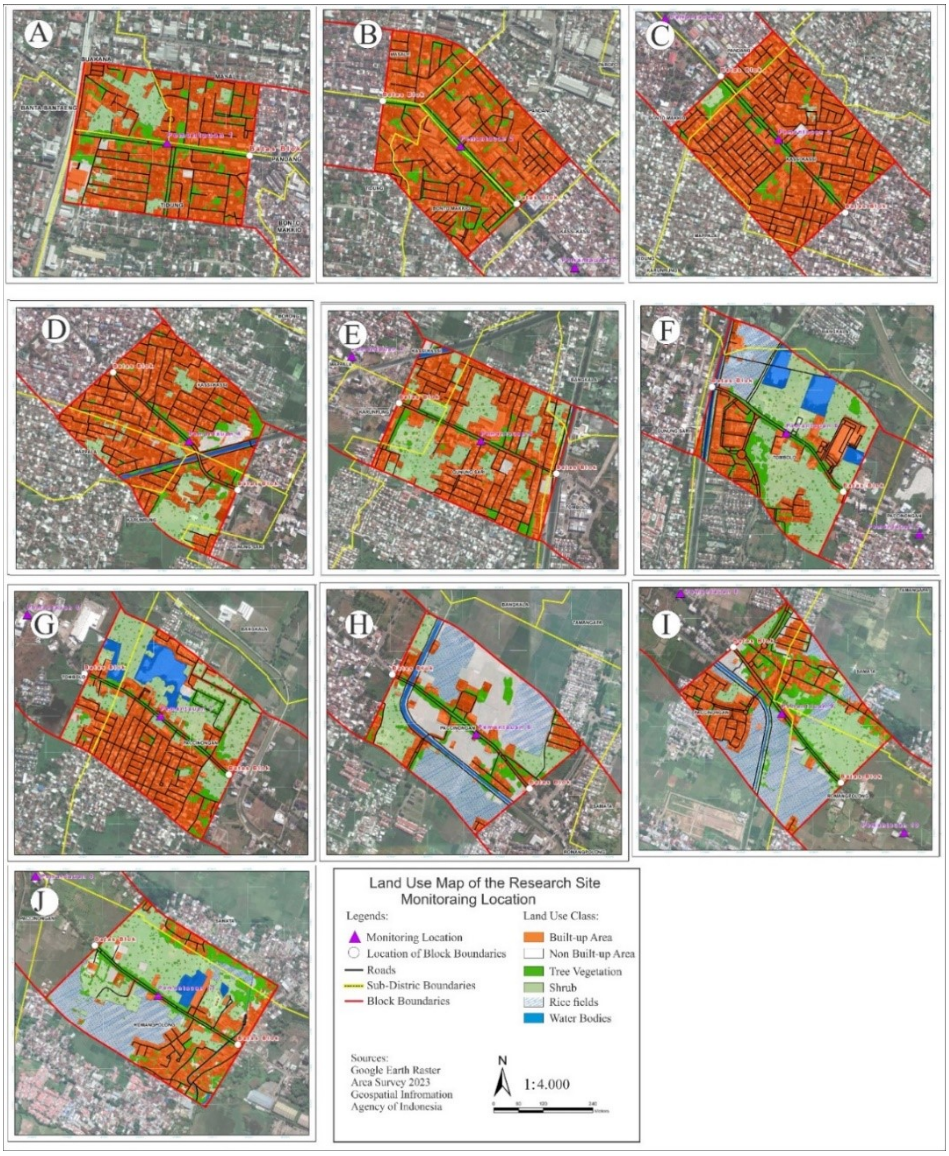

Figure 1: Hertasning-Tun Abdul Razak Road Corridor Area Based on Observation Segment
Source: Author Elaborator

The results of studies that support this research include: (1) Research conducted by Medeiros, et al. (2020) and the study by Chatterjee, et al. (2022) found that urban urban urbanisation and ineffective government institutional systems in metropolitan urban management have an impact on social, economic, and environmental problems; (2) Research conducted by Lara, et al. (2021) found that planning mechanisms that lack integration of urban systems will cause new problems related to economic, social, and environmental aspects. The three studies confirm that ineffective planning systems and urban management institutions as well as weak community participation contribute to the dynamics of peripheral development and the sustainability of metropolitan urban settlement development. Furthermore, this study is more focused on examining and analysing the relationship of traffic performance and land use to climate conditions on the Hertasning-Tun Abdul Razak corridor. Thus, the difference between this study and previous research lies in the dimensions and aspects studied. This means that the study was conducted at the micro-scale of the urban environment, so the measured climate is a microclimate.

The long-term benefits that will be obtained are (i) the availability of air quality information needs as input in spatial planning in the Hertasning-Tun Abdul Razak corridor, (ii) the fulfilment of environmentally sound urban space, and (iii) the implementation of sustainable urban governance. These three things will help the government in formulating planning and spatial planning mechanisms to reduce the negative impacts, especially on-air quality degradation towards the creation of an efficient, quality and sustainable environment.

RESEARCH METHODOLOGY

The quantitative approach in this study was used to test and analyse traffic performance and land use against climatic conditions on the Hertasning-Tun Abdul Razak Road corridor. Traffic performance was assessed based on average speed, side obstacles, vehicle volume, and average density. Land use was assessed based on built-up land, open land, road green space, natural vegetation, rice fields, and water body. Furthermore, climatic conditions were assessed based on temperature, air pressure, relative humidity, and wind speed. Determination of the sample in this study using purposive sampling technique which is determined by the researcher based on certain criteria. This research was conducted from April to August 2020. The data collection methods in this study were observation, survey, and documentation. The instruments used in data collection through observation are field notes and data checklists. Furthermore, the instruments used in data collection through surveys are open-ended questions and closed-ended questions based on the questionnaire set by the researcher. Documentation data in this study include: (1) Mamminasata Metropolitan Spatial Plan obtained through the Office of Spatial Planning, Human Settlements, and Water Resources; (2) Masterplan of large-scale settlement development obtained through housing developers; and (3) Development policies on the Hertasning - Tun Abdul Razak Road corridor obtained through the Regional Development Planning Agency of South Sulawesi Province.

The research variables defined in this study include traffic performance (X_1), land use (X_2), and climatic conditions (Y). Furthermore, traffic performance data was observed based on the conditions and characteristics of resident trips based on origin and destination in relation to average speed, side obstacles, vehicle volume, and average density based on the conditions of the Hertasning - Tun Abdul Razak road corridor. This data was observed based on peak hour traffic volumes. Observations on land use were observed based on the condition of built-up land, open land, road green space, natural vegetation, paddy fields, and water bodies. This data is complemented by interpretation of natural colour composite pleiades satellite imagery with a spatial resolution of 50 cm. Observations of climatic conditions were observed based on temperature, air pressure, relative humidity, and wind speed. The data is complemented by climatic conditions obtained from relevant agencies. The variables of this study are described in Table 1 below.

Table 1: Research Variables

Type of Variable	Variable	Indicator
Independent Variable	Traffic Performance (X_1)	a. Average Speed $(X_{1.1})$ b. Side Obstacles $(X_{1.2})$ c. Vehicle Volume $(X_{1.3})$ d. Average Density $(X_{1.4})$
	Land Use (X_2)	a. Built-up Land $(X_{2.1})$ b. Open Land $(X_{2.2})$ c. Road Green Space $(X_{2.3})$ d. Natural Vegetation $(X_{2.4})$ e. Rice Fields $(X_{2.5})$ f. Water Body $(X_{2.6})$
Dependent Variable	Climate Conditions (Y)	a. Temperature (Y_1) b. Air Pressure (Y_2) c. Relative Humidity (Y_3) d. Wind Speed (Y_4)

The data analysis method in this study uses descriptive statistics, chi-square analysis, and Partial Least Square (PLS) Structural Equation Modeling (SEM), which simultaneously tests the measurement model and structural model (Sarstedt et al., 2021). PLS SEM validates structural models that validate hypothesis testing through predictive models that do not assume specific data scale measurements, thus allowing for small sample sizes below 100 samples (Hair et al., 2017). Furthermore, factor analysis and regression in the PLS model test the relationship between variables through two main stages, namely the outer model and inner model. The analysis formulation used is as follows:

$$X^2 = \sum \frac{(O_i - E_i)^2}{E_i}$$

Where X^2 is the value of the Chi-square statistic, O_i is the frequency of observations in the cells of the contingency table, E_i is the expected frequency in the cell of the contingency table based on the null hypothesis (H_0).

RESULT AND DISCUSSION

Traffic Performance of Hertasning-Tun Abdul Razak Road Corridor

Traffic performance is closely related to the increase in commercial, service, and residential activities located around the Hertasning-Tun Abdul Razak road corridor. These conditions have an impact on increasing traffic volumes characterised by generation and attraction based on the pattern of origin and destination of trips. This means that population mobilisation is characterised by an increase in traffic volume that not only affects road conditions but also the difference in movement that occurs, so the level of service is categorised as category E. This fact illustrates that traffic volume is positively associated with road capacity. The Indonesian Road Capacity Manual (1997) confirms that the main function of roads in the city will result in the pull of population mobilisation towards transport system services. This means that the level of transport service is assessed based on road capacity, road user behaviour, and road traffic volume. Furthermore, traffic flow parameters are important factors to consider in relation to traffic planning. The indicators assessed are traffic volume, speed, and density. Thus, this study considers average speed, side obstacles, vehicle volume, and average density.

Traffic performance on the Hertasning-Tun Abdul Razak road corridor is assessed based on segmentation. The largest traffic volume on the Hertasning-Tun Abdul Razak road corridor is located on segment 1, followed by segment 4, segment 5, and segment 3. The overall traffic volume by segment varies greatly with an average value of 4,250 vehicles per hour. These results confirm that traffic volume is closely related to land use development along the Hertasning-Tun Abdul Razak road corridor. Furthermore, the average speed by segment shows an increasing trend in vehicle speed although not significant. Vehicle density and side obstacles show a decreasing trend based on each monitoring segment. This confirms that vehicle density and the number of side barriers are closely related to population mobility characterised by commercial, service, and residential activities. Traffic and Land Use Performance on Climate Conditions of the Hertasning-Tun Abdul Razak Corridor is presented in Figure 2 below.

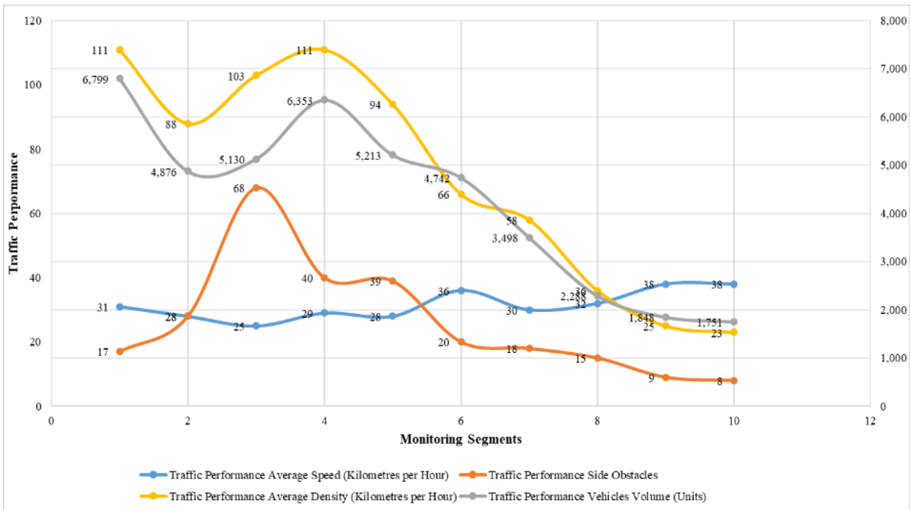

Figure 2: Traffic Performance of Hertasning - Tun Abdul Razak Road Corridor
Source: Analysis Result

Land Use of the Hertasning-Tun Abdul Razak Road Corridor

Urbanisation and urban expansion are closely related to land use change that occurs on the Hertasning-Tun Abdul Razak road corridor. These conditions result in increased socio-economic activities and changes in urban microclimate characteristics. These changes are more due to increased population mobility and the intensity of built-up areas that tend to increase over time and contribute to the availability of land for green open areas that affect the condition of natural vegetation and have an impact on global warming. The indicators assessed in this study are built-up land, open land, road green space, natural vegetation, paddy fields, and water bodies.

Land use on the Hertasning-Tun Abdul Razak road corridor varies greatly by segment. The largest built-up area in segment 4 is shown with socio-economic, office, service, and commercial activities. Furthermore, land uses such as open land, paddy fields, and water bodies tend to expand their areas from Segment 1 to Segment 10. This occurs because there is still some land in Segment 6 to segment 10 that has not been fully developed, with most of it still being used as paddy fields. Meanwhile, the use of road green space shows a relatively stable consistency from Segment 1 to Segment 10. Thus, land use confirms urban expansion in the Hertasning-Tun Abdul Razak road corridor area. McGee (1991) asserts that areas along corridors traversed by transport systems undergo spatial, economic, social, and cultural transformations, which ultimately lead to a significant shift from rural to urban characteristics. The land use of the Hertasning-Tun Abdul Razak road corridor is presented in Figure 3.

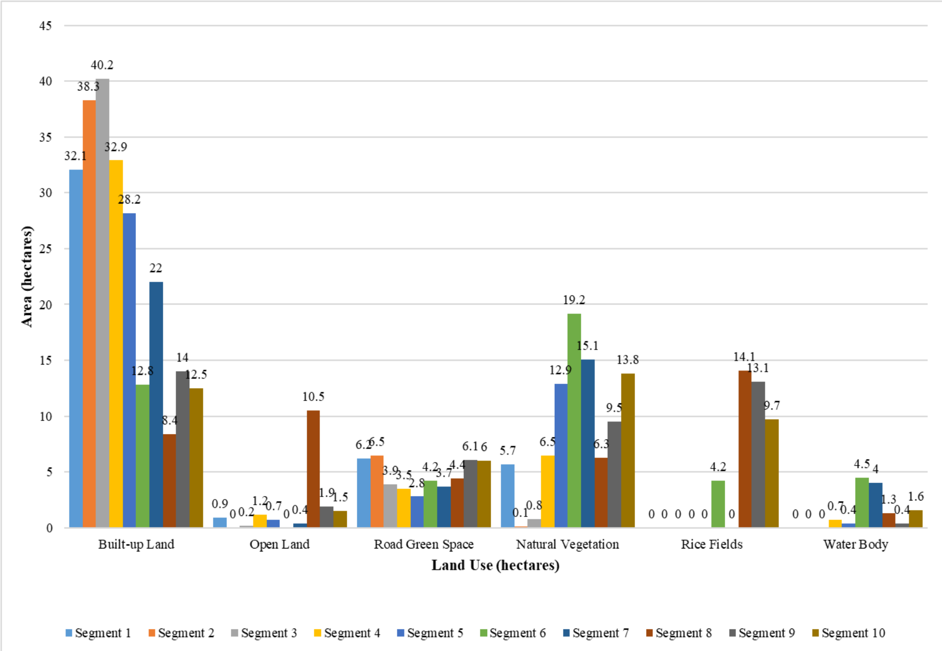

Figure 3: Land Use of the Hertasning-Tun Abdul Razak Corridor
Source: Analysis Result

Climate Condition of Hertasning-Tun Abdul Razak Road Corridor

The measurement of urban microclimate conditions is strongly influenced by the physical conditions and socio-economic activities of the community. The study involved measuring climatic conditions with the parameters of temperature, air pressure, relative humidity, and wind speed. The measurement results show that the air temperature from segment 5 to segment 10 is about 2℃ higher compared to segment 1 to segment 4. This contrasts with the relative humidity which tends to decrease from Segment 1-10. This decrease in humidity could be since segments 5-10 consist of open land, resulting in greater sunlight intensity. In addition, the amount of road green space in segment 5 to segment 10 is also less compared to segment 1 to segment 4, which also affects the relative humidity. Air pressure conditions were stable for all monitoring segments, at 746 mmHg. However, the wind speed varied in each segment. The lowest wind speed occurred in segments 1 and 2, at 0.7 m/s, as many buildings and trees blocked the wind. On the other hand, wind speeds are higher in segments 4, 9 and 10, which are more open, allowing the wind to move more freely. The climatic conditions of the Hertasning-Tun Abdul Razak road corridor are presented in Figure 4.

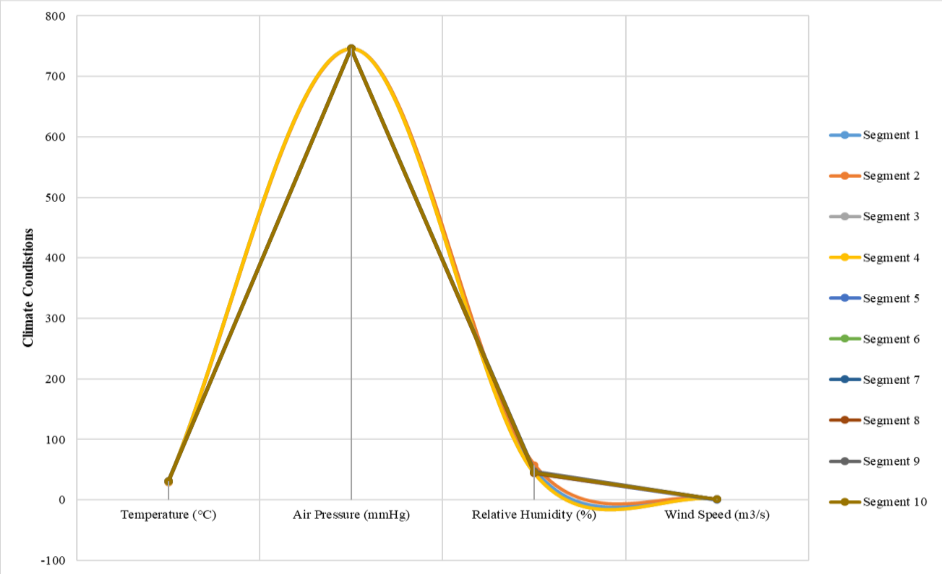

Figure 4: Climate condition of Hertasning-Tun Abdul Razak corridor
Source: Analysis Result

Structural Equation Modelling

Traffic performance with a value on indicator $X_{1.1}$ is -0.921, $X_{1.2}$ is 0.842, $X_{1.3}$ is 0.874, and $X_{1.4}$ is 0.630. Land use variables, the loading value of the indicator $X_{2.1}$ is -0.826; $X_{2.2}$ is 0.287, $X_{2.3}$ is -0.428, $X_{2.4}$ is 0.881, $X_{2.5}$ is 0.426, and $X_{2.6}$ is 0.822. Furthermore, climate conditions, the loading value on the Y_1 indicator is 0.944, Y_3 is -0.914, and Y_4 is 0.097. Furthermore, indicators with a loading factor value > 0.6 are declared valid. Thus, the loading factor value is valid for each indicator, so test the second algorithm to see the validity of the indicator as a measure of its construct. The PLS Algorithm 2 model path diagram has no negative variance, so the existing indicators are declared valid. Furthermore, the loading factor value for each indicator shows that all indicators get a loading factor value above 0.6 where the loading value> 0.6 is said to be valid, so that all indicators are declared valid as a measure of the construct. Thus, the indicators of land use are determined by indicators of natural vegetation and water bodies, traffic performance is determined by indicators side obstacles, vehicle volume, and average density, and climatic conditions are determined by air temperature. The calculation of the R^2 value of climate conditions is 0.623 which can be interpreted that climate conditions are determined by land use and traffic performance by 62.3%. The Relationship Model of Traffic Performance and Land Use to Climate Conditions of the Hertasning-Tun Abdul Razak Corridor is presented in Figure 5.

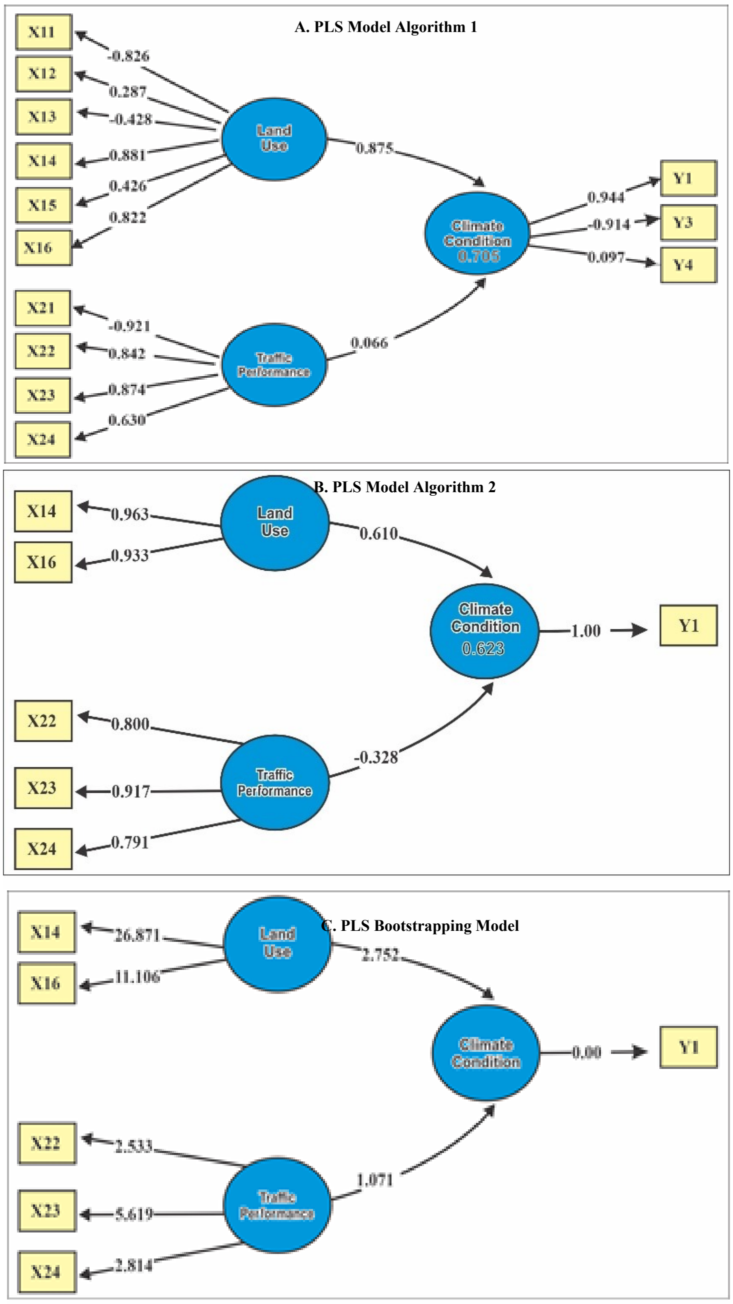

Figure 5: (A-C) Relationship Model of Traffic Performance and Land Use to Climate Conditions of Hertasning-Tun Abdul Razak Corridor
Source: Analysis Results

Table 2: The Relationship of Land Use and Traffic Performance to Climate Conditions in the Hertasning-Tun Abdul Razak Road Corridor

	Original Sample (O)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	P Values
Traffic Performance -> Climate Condition	-0.328	0.306	1.071	**0.285**
Land Use -> Climate Condition	0.610	0.222	2.752	**0.006**

Source: Analysis Results

Table 2 shows the testing of the relationship between land use and traffic performance on climatic conditions in the Hertasning-Tun Abdul Razak road corridor. The test results show the effect of land use on climatic conditions showing the results of the T-Statistic value of 2.752 > 1.96 or a P value of 0.040 < 0.05 then H_0 is rejected. This means that land use influences climatic conditions. These findings confirm that land use on the Hertasning-Tun Abdul Razak road corridor causes an increase or decrease in climate conditions and air temperature. Furthermore, land use change is related to the socioeconomic activities of the community, including residential, urban, and agricultural areas (Camara et al., 2019; Ibrahim & Ash'aari, 2023). The rapid growth of the urban population and various development activities will increase land demand, leading to pressure to convert agricultural land to residential and commercial uses (Erasu Tufa & Lika Megento, 2022; Zaki et al., 2023). Furthermore, testing the effect of traffic performance on climate conditions shows the T-Statistic value of 1.071 < 1.96 or the P value of 0.285 > 0.05, so H_0 is accepted. This means that traffic performance does not significantly affect climate conditions. This suggests that an increase or decrease in traffic performance along the Hertasning-Tun Abdul Razak road corridor does not significantly alter climatic conditions, particularly air temperature. This finding contrasts with the literature that suggests that vehicle density, as part of traffic performance indicators, can affect climate with associations to air quality, human health, and climate change (Huang et al., 2020; Ogunkunle & Ahmed, 2021). This is closely related to the role of the transport system in increasing greenhouse gas emissions that can cause climate change on a macro scale (Kontovas & Psaraftis, 2016; Shahidan & Shafie, 2020). The difference in research findings with previous studies is due to the difference in measurement scale, where this study was conducted in a micro-scale urban environment, by measuring microclimate. At the micro scale, the transport sector does not directly contribute to microclimate improvement but affects the macroclimate through the greenhouse gas phenomenon.

The sustainability of peri-urban development along the Hertasning-Tun Abdul Razak road corridor is examined using a holistic approach. The dynamics of peri-urban areas are characterised by the interaction between urban sprawl and rural characteristics. Efficient and sustainable land use management, through zoning arrangements, and distribution of space between residential, commercial, and green open space areas, directly contributes to the formation of a sustainable city (Surya et al., 2020; Daunt et al., 2021). Furthermore, the role of the transport system in reducing air pollution, encouraging public transport services, and developing green infrastructure that supports congestion reduction, air quality improvement, and provision of green open spaces. Thus, peri-urban development efforts include strategies for resilience to climate change and disaster risk management as well as the fulfilment of green open space towards environmental sustainability and improved quality of life. The sustainability of peri-urban areas is presented in Figure 6 below.

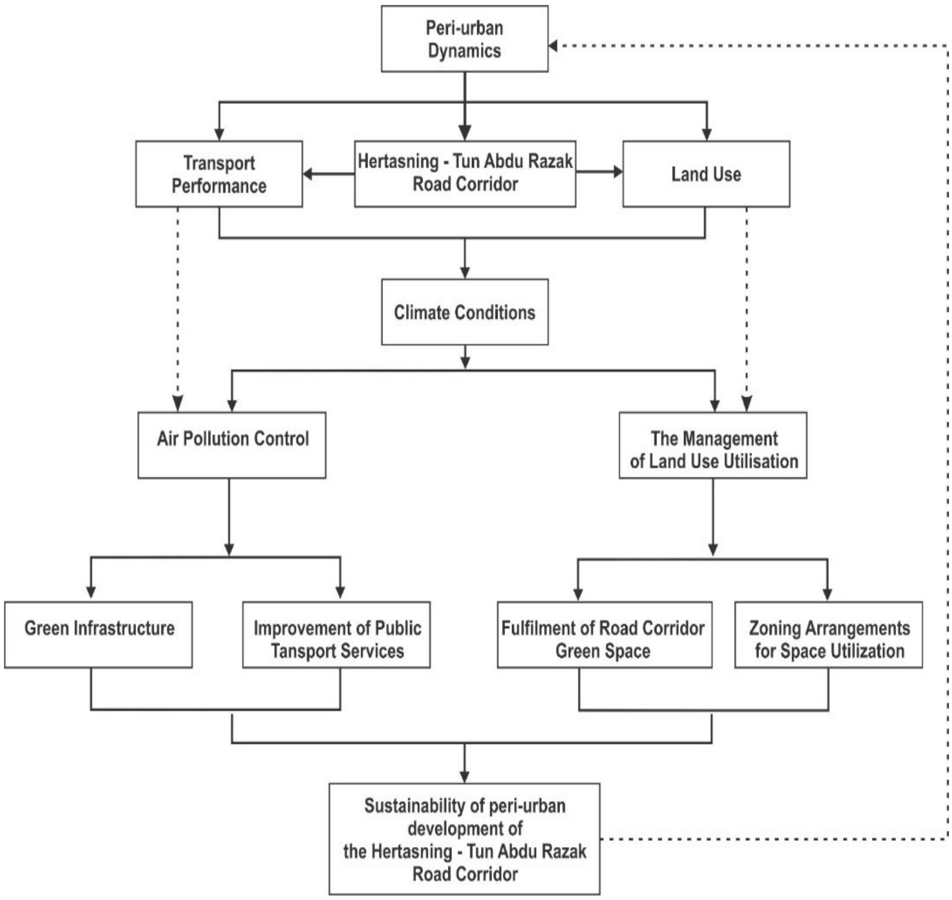

Figure 6: Sustainable Development Scheme in Peri-Urban Area of Hertasning-Tun Abdul Razak Road Corridor
Source: Author Elaborator

CONCLUSIONS

The dynamics of the development of peripheral areas have increased socio-economic activity, population mobility that has an impact on the transport system and land use on changes in urban microclimate characteristics on the Hertasning-Tun Abdul Razak road corridor. Climatic conditions are characterised by air quality and land use management and traffic performance. The statistical test results show that land use variables affect climate conditions. Thus, land use change on the Hertasning-Tun Abdul Razak road corridor is positively associated with an increase in urban temperature. Increases in urban temperatures are directly linked to increases in anthropogenic activities and their effects on land use change around the Hertasning-Tun Abdul Razak road corridor.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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