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Population mobility and urban transport management: perspectives environmental quality degradation and sustainable development of suburban Makassar City, Indonesia

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Abstract

The expansion of the area towards suburban areas accompanied by suburbanization has an impact on the conversion of productive agricultural land and transportation movement systems. This study aims to analyse land use change works as a determinant of environmental degradation in suburban areas, the effect of land use changes, socio-economic activities, population mobility and transportation systems on environmental quality degradation, and models for handling land use, population mobility, transportation infrastructure and system management transportation towards sustainable development of suburban areas. This study uses a sequential qualitative-quantitative approach. Data obtained through observation, survey and documentation. The results of the study show that the intensity of land use change coupled with population mobility, in addition to affecting the urban transportation system based on the pattern of origin and destination of travel, also has an impact on the environmental quality degradation of suburban areas. Changes in land use, socio-economic activities, population mobility and transportation systems has an effect in the environmental quality degradation of suburban areas with a coefficient of determination of 95.65 percent.. This study recommends the application of a land use management model, population mobility, and transportation infrastructure towards the sustainability of the suburbs of Makassar City, Indonesia.

Keywords: land use change, population mobility, transportation system, sustainable development

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Introduction

The expansion of the Makassar City area towards suburban areas contributes to changes in land use, transportation systems and population mobility. The change in land use is marked by various development activities being developed, namely industry, commercial activities, services, education and health services. Land use change has specific and cumulative effects on air and water quality, waste generation, climate and human health (Lu, Y. *et al*. 2021; Zhao, Y. *et al*. 2021). Increased socio-economic activities have an impact on population mobility based on the pattern of origin and destination of travel (Graells-Garrido, E. *et al.* 2021; Heine, C. *et al.* 2021). The spatial dynamics of suburban areas which are dominantly developed for housing and settlement development are positively related to an increase in traffic volume on main roads, traffic congestion and disturbances to residents' travel patterns (Nair, DJ. *et al*. 2019; Nozdrovická, J. *et al.* 2020; Surya, B. *et al.* 2020a). Furthermore, the intensity of land use change and population mobility, in addition to having an impact on traffic congestion, also contributes to air quality pollution originating from motor vehicle exhaust emissions. Air pollution not only has an impact on climate change but also affects public health (Mani-

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salidis, I. *et al.* 2020). Increased levels of CO_2 in the air have an impact on public health and affect social stability and economic development (Wu, J. and Pu, Y. 2020; Fears, R. *et al.* 2021). Thus, the complexity of land use and population mobility besides affecting the transportation system also has an impact on environmental pollution (Nugmanova, A. *et al.* 2019; Surya, B. *et al.* 2021a). Development activities that tend to increase in suburban areas cause changes in land cover and a decrease in environmental quality (Hasan, S. *et al.* 2020; How Jin Aik, D. *et al.* 2021). Thus, the spatial designation developed in the outskirts of Makassar City has been identified as having exceeded the carrying capacity of the environment and threatens the sustainability of the ecosystem (Surya, B. *et al.* 2021b).

The distribution of the flow of goods and services coupled with the mobility of the population from the outskirts to the city centre has led to an increase in the flow of transportation movements on the main road corridors of the suburbs. Thus, the city government is faced with the challenge of handling and providing adequate public transportation facilities that are integrated with the land use system (Shen, L. *et al.* 2018; Surya, B. *et al.* 2020b). Furthermore, socio-economic activities that tend to increase have an impact on the complexity of land use and transportation systems in the suburbs of Makassar City. That is, the transportation system and land use are an integral part of the urban system in relation to population mobility (Clement, C. 2015; Rodrigue, P.J. 2020). This tendency is caused by the weak control over the use of space and inconsistency in the implementation of the spatial plan that has been determined (Sadli, M. 2008; Surya, B. *et al.* 2020c). Thus, the complexity of land use and allocation of utilization in suburban areas becomes very important and strategic to be immediately addressed in relation to the expansion of the Makassar City area towards suburban areas.

This study aims to answer research questions, namely: (1) How does land use change work as a determinant of environmental degradation in suburban areas? (2) How big is the influence of changes in land use, socio-economic activities, population mobility and transportation systems on environmental degradation? and (3) How is the model for handling land use, population mobility, transportation infrastructure, towards the management of the transportation system and the sustainability of the development of suburban areas? Thus, the contribution of this study is expected to be the basis and reference for the government in formulating development policies related to land use and transportation system management towards sustainable development of suburban areas for the case of metropolitan cities.

Theoretical background

The tendency of land use change is dominantly influenced by the demands of meeting the needs of urban development, namely housing and settlements, transportation infrastructure and other socio-economic activities. Built-up areas that are developed in suburban areas contribute to land cover and conversion of productive agricultural land (Lee, J. *et al.* 2020; Wang, F. *et al.* 2020). The intensity of land use change has an impact on population mobility towards generation and transportation pull based on the population's travel pattern from the area of origin to the area of destination (Chen, Y. *et al.* 2019; Chemura, A. *et al.* 2020). Thus, the mobility pattern of the urban population is very important to be formulated in the mechanism of transportation planning and urban traffic management (Guo, Y. *et al.* 2020). Land conversion is basically a form of human intervention in land use to meet the needs of its socio-economic activities (Hersperger, A.M. *et al.* 2018; Mandeli, K. 2019). Furthermore, the socio-economic dynamics of the community in relation to changes in land use have direct influence on urban aesthetics, land values and transportation systems towards decreasing environmental quality (Segura, E.A. *et al.* 2020; Tanaka, K. and Hashiguchi, Y. 2020).

Development activities that tend to increase in addition to contributing to land use change also have an impact on population mobility and affect the urban transportation system based on patterns of origin and destination. Increased socio-economic activity in suburban areas has an influence on the spatial social structure, road network system and distribution pattern of urban service functions (Hidayati, I. *et al.* 2019; Surya, B. *et al.* 2021c). Thus, an increase in population mobility followed by an increase in urban activity causes a decrease in the environmental quality of suburban areas (Carrasco, J.C. *et al.* 2021; Ribeiro, P. *et al.* 2021). Development investments carried out through the expansion of urban areas towards suburban areas have an impact on changes in land cover and interactive transportation systems towards the formation of the built environment (Huang, G. *et al.* 2020). Furthermore, the effects caused by the complexity of land use, namely the increase in traffic volume, environmental pollution and public health. These three things require handling and control measures towards the sustainability of suburban areas (Fernandes, P. *et al.* 2019).

Sustainable development is centred on intergenerational justice that rests on the pillars of three different but interconnected dimensions, namely the environment, economy and social (Mensah, J. and Casadevall, S.R. 2019). Cities face increasing environmental, social and economic challenges that threaten the resilience of urban areas (Bush, J. and Doyon, A. 2019). The increasing levels of human population in urban areas and the importance of urban functions pose a number of ecological challenges (Cepeliauskaite, G. and Stasiskiene, Z. 2020). The World Commission on Environment and Development (Brundtland, G.H. 1987) states that sustainable cities are built through caring and paying attention to natural environmental assets, paying attention to the use of resources and minimizing the impact of activities on nature. Sustainability in its broadest sense is the capacity of natural systems to endure and to remain diverse and productive over time (Almusaed, A. and Almssad, A.E. 2018). Furthermore, indicators that can be used to measure the sustainability of development are ecological, economic and social (Branch, M. 1995). Thus, sustainable development is a goal to be achieved towards a balance between economic, social and environmental in order to create a stable and quality society. Quality of life and sustainability i.e., the creation of jobs, reducing inequality, local investment, responsible social practices or environmental protection (Landin, S.A. 2020). The hypothesis built in this study, namely changes in land use, socio-economic activities, population mobility and transportation systems affect the environmental quality degradation of suburban areas.

Conceptual and methodological framework

Land use change is the use of land for the needs of urban activities on a land that is different from previous activities, both for commercial, industrial, and services as well as for housing and settlement development needs. Changes in land use are closely related to government policies in terms of expanding urban areas. Furthermore, population mobility is assessed based on three interests, namely physical, economic and socio-cultural. Population mobility is closely related to the pattern of origin and purpose of travel for work, trade and social purposes, its relevance to socio-economic activities developed at certain locations both in the city centre and in suburban areas. The transportation system is a link between passengers or goods, transportation infrastructure and facilities that interact in a series of passenger or goods movement. Meanwhile, the decline in environmental quality is understood in the context of the non-functioning of environmental components. Thus, the weak control of spatial use in the development of suburban areas coupled with the intensity of land use changes, increased socio-economic activities, population mobility and transportation systems will have an impact on environmental quality degradation.

This research was carried out in the suburbs of Makassar City. The choice of research location was based on the following considerations: (1) Makassar City is the main city in the Mamminasata Metropolitan urban system; (2) The expansion of Makassar City towards suburban areas has an impact on the urban spatial integration of the Mamminasata Metropolitan. This condition is indicated by the presence of the city's main road corridors, including: (i) the Perintis Kemerdekaan road corridor with a road length of 11.93 kilometres that functions to connect Makassar City with Maros Regency, (ii) the Hertasning-Samata road corridor with a road length of 8.76 kilometres serves to connect Makassar City with Gowa Regency, and (iii) the Metro Tanjung Bunga road corridor with a road length of 6.70 kilometres serves to connect Makassar City with Takalar Regency. Furthermore, the population of Makassar City in 2016 was 1,469,601 people, in 2019 there were 1,526,677 people, and in 2021 there were 1,545,455 people. The transfer of land use functions and the increase in socio-economic activities developed in suburban areas are marked by the presence of activities, including: (1) Housing and settlements occupying an area of 2,468.61 ha; (2) Commercial activities occupy an area of 433.88 ha; (3) Industry and warehousing occupy an area of 59.4 ha; and (4) Education and health occupy an area of 182.89 ha (BPS Makassar City, 2021). The suburbs of Makassar City which are the object of research are presented in *Figure 1*.

This study uses a qualitative-quantitative approach sequentially. The case studies in this study were selected with the following considerations: (1) The transportation system for the suburbs of Makassar City is specific; (2) The observed cases have a fairly prominent consistency in the dynamics of development in the suburbs of Makassar City. Thus, to obtain data in the field it is necessary to combine a qualitative-quantitative approach. Observations in this study were used to track data, namely (i) land use changes, (ii) socio-economic activities, and (iii) spatial use patterns in suburban areas. The instruments used in data collection were field notes, periodic notes, checklists and location base maps. This study also uses various documents related to the development of suburban areas of Makassar City. The documents referred to include: (1) Traffic volume data obtained through the Makassar City Transportation Service; (2) Data on land use change and Makassar suburban spatial plans were obtained through the Makassar City Regional Development Planning Agency; and (3) Data on socio-economic activities in suburban areas are obtained through the District Office. The survey in this study used a questionnaire instrument. Measurement of data using an ordinal scale based on the questions posed in the questionnaire. Thus, the questionnaire in this study was used to track data, namely (i) land value and price; (ii) socio-economic activities, (iii) population mobility, (iv) transportation system, and (v) environmental degradation in the suburbs of Makassar City. Respondents who filled out the questionnaire in this study, namely (i) economic actors, (ii) community who carry out mobility, and (iii) local government. Respondents in this study were determined using a purposive sampling technique which the researchers determined based on certain criteria. Determination of the research sample refers to Neyman, J. (1934).

The formulation used is as follows:

$$n_h = \frac{N_h}{N} n \quad (1)$$

where n_h is the sample size of each stratum, n must be allocated according to (proportionally). Sampling is simple random at each stratum, so that the probability $\frac{N_h}{N}$ of each sampling unit in the strata h to be selected as a subsample is $\frac{n_h}{N_h} = F$. Each unit in the population has an equal chance of being selected as the sample. The number of samples in this study was determined by as many as 300 respondents. The suburban transportation system data in this study uses the analysis method of traffic volume, road capacity, and degree of saturation.

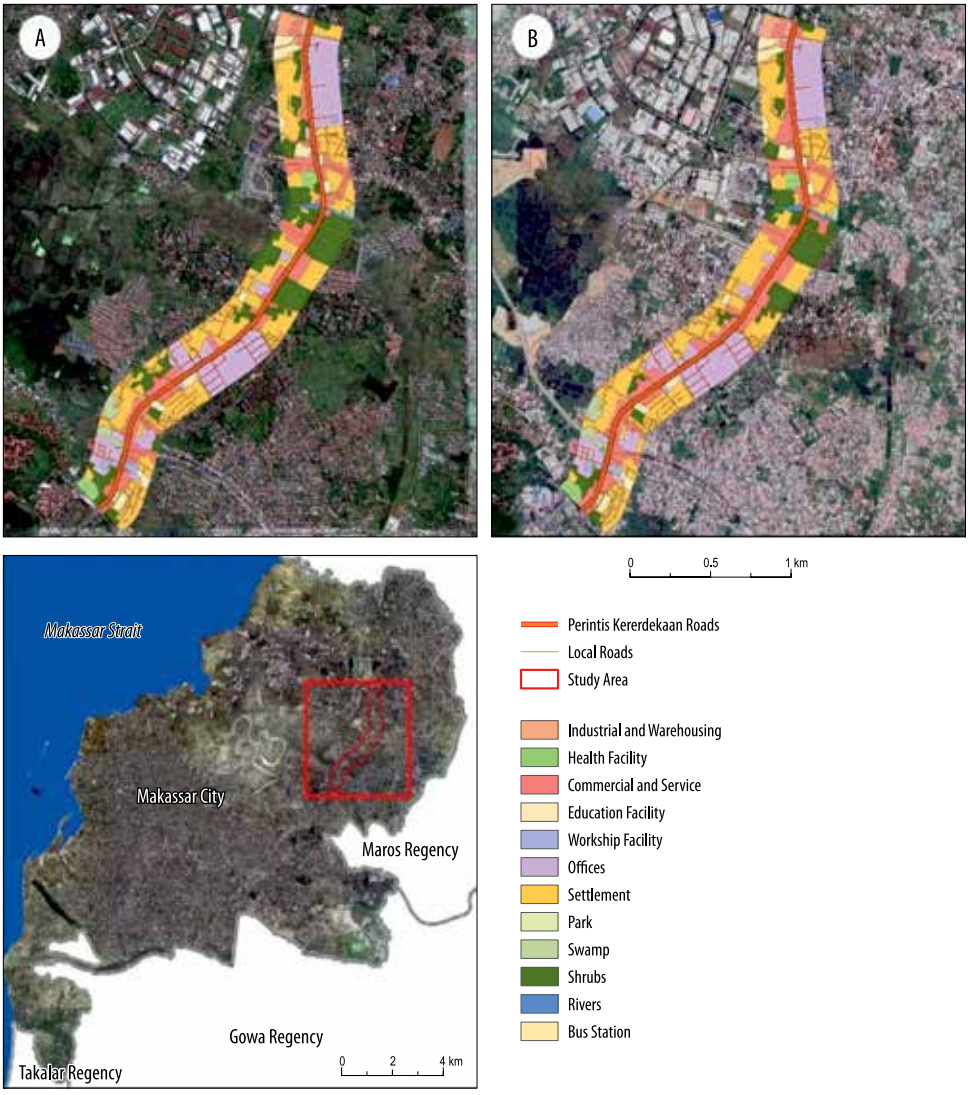

Fig. 1. Research location in the suburbs of Makassar City with land use in 2016 (A) and in 2019 (B). *Sources:* Google Earth Survey Arca Raster 2020, Geospatial Information Agency of Indonesia.

The formulation used is as follows:

$$q = \frac{n}{t}, \tag{2}$$

$$C = Co \cdot FC_w \cdot FC_{sp} \cdot FC_{cs}, \tag{3}$$

$$DS = \frac{Q}{C}, \tag{4}$$

where q is the volume of traffic passing through a certain point, n is the number of vehicles passing that point in the observation time interval, t is the observed time interval. C is the capacity (pcu/hour), Co is the basic capacity (pcu/hour), FC_w is the direction separation adjustment factor, FC_{sp} is the side drag adjustment factor, and FC_{cs} is the city size adjustment factor. DS is the degree of saturation, Q is traffic volume (pcu/hour), and C is capacity (pcu/hour). Multiple re-

gression analysis method is used to analyse the causal relationship of several independent variables, namely land use change (X_1), socio-economic activities (X_2), population mobility (X_3), transportation system (X_4), to the dependent variable, namely the environmental quality degradation (Y).

The formulations used for multiple regression analysis and correlation analysis are as follows:

$$Y = a + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + \dots b_nX_n + \varepsilon, \quad (5)$$

$$r_{xy} = \frac{n\sum X_i y_i - \sum X_i \sum y_i}{\sqrt{n\sum X^2{}_i - (\sum X^2{}_i)^2}\sqrt{n\sum y^2{}_i - (\sum y_i)^2}} \quad (6)$$

where Y is the dependent variable, a is a constant, b_1, b_2, b_3, b_4 and b_n are the regression coefficients X_1, X_2, X_3, X_4 and X_n are independent variables, and ε is the residual value. Furthermore, n is a lot of data or samples, r_{xy} is the correlation coefficient between variable X and variable Y, $\sum X_i y_i$ is the number of the multiplication between variables X and Y, $\sum X^2_i$ is the sum of the squares of the X value, $\sum y^2_i$ is the sum of the squares of the Y value, $(\sum X_i)^2$ is the sum of the X values then squared, and $(\sum y_i)^2$ is the Y value then squared. Furthermore, implementation of Structural Equation Modelling (SEM) in this study refers to several exogenous variables, including: (1) The land use construct variable is measured by indicators, namely space utilization (X_1), built area (X_2) and spatial function (X_3). (2) The construct variable of population mobility is measured by indicators, namely the means of transportation used (X_4), availability of transportation modes (X_5), origin of travel (X_6) and destination of travel (X_7). (3) The construct variable of transportation infrastructure is measured by indicators, namely the road network system (X_8), road body capacity (X_9), road services (X_{10}), road conditions (X_{11}). Furthermore, the constructs of the endogenous latent variables include: (1) The latent variables of transportation management are measured by indicators, namely accessibility (y_1), generation and attraction of movement (y_2), distribution of movement (y_3), mode selection (y_4), distribution of movement (y_5) and behaviour road users (y_6); (2) The latent variables of suburban development sustainability are measured by indicators, namely environmental (y_7), economic (y_8), and social (y_9).

The SEM analysis method uses the following formulation:

$$\eta = \alpha + B\eta + \Gamma\xi + \zeta, \quad (7)$$

$$\eta - B\eta = \alpha + \Gamma\xi + \zeta, \quad (8)$$

$$(I - B)\eta = \alpha + \Gamma\xi + \zeta, \quad (9)$$

$$\eta = (I - B)^{-1}\alpha + \Gamma\xi + \zeta, \quad (10)$$

where α is the intercept vector, B and Γ is the coefficient matrix and $\zeta = \zeta_1 \cdot \zeta_2 \cdot \zeta_m$ is the error vector in the structural equation, element B presents variable influence η and variable η other, and elements Γ present a direct influence of variables ξ in variable η. It is assumed that ξ not correlated with ζ and $I - B$ is nonsingular. Furthermore, is the intercept vector m x 1, η is the endogenous latent variable m x 1, B is the coefficient matrix of the endogenous latent variable m x m, Γ is the coefficient matrix of the exogenous latent variable m x n, ξ is the exogenous latent variable vector n x 1, ζ structural model error vector relationship between η and ξ size m x 1. Random vector η and ξ not measured directly but through the indicator, namely the variable $Y^T = (y_1, y_2, \dots y_p)$ and $X^T = (X_1, X_2, \dots X_p)$.

Results and discussion

Changes in land use, population mobility and decline in environmental quality

The expansion of the Makassar City area has an impact on changes in land use, increased socio-economic activities and population mobility and transportation systems based on patterns of origin and destination of travel. Population growth and land requirements that tend to increase are positively associated with discrepancies between land use patterns and the designation plans stipulated in the city spatial plan (Khadiyanto, P. 2005;

Surya, B. *et al.* 2021a). Thus, changes in land use coupled with increased social activities are determinant factors that affect population mobility and the transportation system in the direction of decreasing the environmental quality of suburban areas. Changes in land use in the suburbs of Makassar City are presented in *Table 1* which shows changes in land use during the period 2010–2021.

Socio-economic activities that developed in the outskirts of Makassar City were marked by the presence of several activity functions, including: (1) Commercial activities increased by 5.15 percent; (2) Housing and settlement development increased by 1.10 percent; (3) Educational activities occupy an area of 7.65 ha or 3.73 percent; (4) Industrial and warehousing activities occupy an area of 3.06 ha or 1.49 percent. These four activities are the driving force for increasing population mobility and transportation systems in the suburbs of Makassar City. This means that the development of suburban areas will be faced with the challenge of providing land that is integrated with the urban transportation system (Surya, B. 2016; Shen, L. *et al.* 2018). Population mobility which tends to increase will require the support of providing adequate transportation facilities in relation to the mobility of goods and passengers from the suburbs to the city centre. The facts found in the field indicate that two factors that influence the increase in land prices are related to the complexity of land use and transportation systems in the suburbs of Makassar City, namely: (1) Related to the selling value of land in relation to the function of economic activities; (2) Use value land and spatial functions that develop have a direct influence on increasing population mobility. These two factors are positively associated with an increase in the value and price of land economically and affect the transportation system in the suburbs of Makassar City. Thus, distance, accessibility, transportation infrastructure, and economic activity affect the use value and price of land in suburban areas (Hudalah, D. and Firman, T. 2012). Thus, changes in land use and the function of economic activities contribute to changes in transportation characteristics and population mobility based on the pattern of origin and destination of travel and their effect on spatial dynamics and environmental degradation in the suburbs of Makassar City. The characteristics of transportation in relation to land use change are presented in *Figure 2*.

Changes in transportation characteristics in the suburbs of Makassar City (see *Figure 2*, A) are influenced by two main factors, namely economic activities and social activities related to land use. This means

Table 1. Utilization of space on the suburban of Makassar City

Type of activity	Space utilization			
	2010		2021	
	ha	%	ha	%
Settlement	71.39	34.77	73.65	35.87
Offices	42.36	20.63	42.64	20.77
Commercial and services	31.35	15.27	41.92	20.42
Education facility	7.65	3.73	7.65	3.73
Health facility	2.77	1.35	2.77	1.35
Industrial and warehouse	3.06	1.49	3.06	1.49
Bus station	2.27	1.11	2.27	1.11
Worship facility	2.12	1.03	2.12	1.03
Shrubs	36.99	18.01	24.03	11.70
Swamp	3.79	1.85	3.64	1.77
Park	0.37	0.18	0.37	0.18
Rivers	1.21	0.59	1.21	0.59

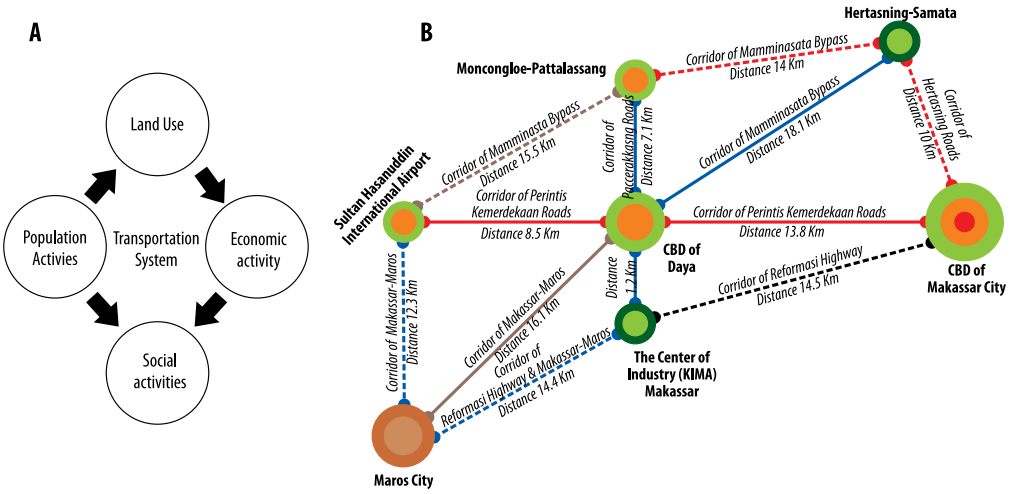

Fig. 2. Socio-economic activities and transportation system. A = Transportation systems and activity patterns; B = Pattern of origin and destination of travel. *Source*: Author's elaboration.

that changes in land use in the corridor are closely related to socio-economic activities developed by the community. Field facts found indicate that three factors are related to socio-economic activities in the suburbs, namely (i) economic productivity, (ii) consumption, and (ii) distribution. These three things are positively associated with the transportation system and environmental degradation. This means that changes in land use and the function of urban activities are closely related to the characteristics of transportation and population mobility based on the pattern of origin and destination of travel and their influence on the spatial dynamics of the suburbs of Makassar City. Four factors affect the urban transportation system in relation to road infrastructure, namely (i) basic capacity, (ii) effective lane width, (iii) distribution direction, and (iv) side barriers. The interpretations proposed (see *Figure 2*, B) are: (1) Population mobility from residential locations to commercial, industrial, educational, workplace and health services; (2) People's travel orientation to the city centre is dominant using private vehicles. The increase in socio-economic activity has an impact on the generation and attraction of transportation. Field facts found indicate that population mobility coupled with land use complexity is positively associated with environmental degradation in the suburbs of Makassar City. The road capacity and degree of saturation on the main road corridor in the suburbs of Makassar City are presented in *Figure 3*.

It shows the relationship between traffic volume, road capacity and degree of saturation in the suburbs of Makassar City. Interpretations can be proposed regarding these conditions, including: (1) The degree of road saturation at the location of the business centre and power plant is 0.450 with a daily traffic volume of 94,220 pcu/hour; (2) The degree of road saturation at the location of the PLTU and Sermani industry is 0.339 with a daily traffic volume of 71,064 pcu/hour; (3) The degree of road saturation at the Makassar Industrial Estate location is 0.266 with a daily traffic volume of 55,766 pcu/hour; (4) The degree of road saturation at the Hasanuddin International Airport is 0.291 with a daily traffic volume of 60,826 pcu/hour. These results confirm differences in daily traffic volume and road network saturation levels. This means that the scale of urban activ-

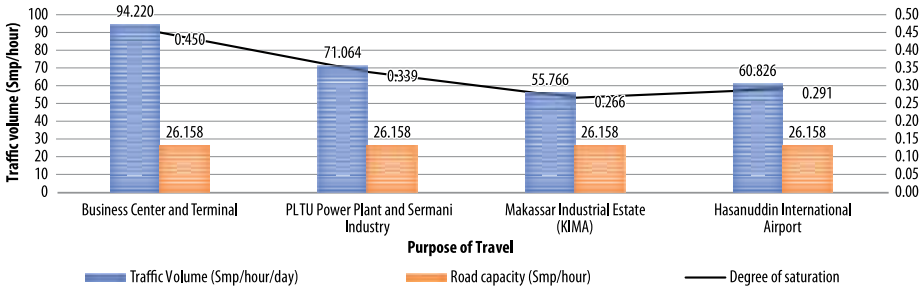

Fig. 3. Traffic volume, road capacity and degree of saturation of main road corridors in suburbs of Makassar City. *Source:* Primary data.

ity affects the traffic volume and the level of saturation of urban roads in the suburbs of Makassar City. Socio-economic activities will affect the availability of urban transportation (Nadi, P.A. and Murad, A.K. 2019; Surya, B. *et al.* 2021b). Air and noise pollution are externality factors generated by road transport and affect environmental quality (Zefreh, M.M. and Torok, A. 2021). The impact of development on environmental quality degradation in the suburbs of Makassar City is presented in *Figure 4* demonstrating the decline in environmental quality in the suburbs of Makassar City.

The interpretations that can be put forward for these results include: (1) The dominant urban activities that contribute to the decline in environmental quality, namely the volume of waste generated by informal economic activities with a value of 9.72 percent; (2) 9.53 percent of the volume of waste generated by formal economic activities; (3) 9.25 percent of waste is generated by informal economy activities and traditional markets; and (4) 9.16 percent generated by industrial waste. These results confirm that the complexity of land use and transportation systems contributes positively to environmental pollution. The transportation system on the outskirts of Makassar City, shows that the complexity of land use has an impact on increasing daily traffic volume, travel distances and inefficient transportation costs. The use of public transportation facilities and private vehicles is an intermediary variable that shows the relationship between land use, travel destination, travel time, and distance based on the mode of transportation used by residents in mobility (Silva, J.A. 2018). The increase in traffic volume and the complexity of land use has an impact on three important things that interact with each other, namely activities, transportation networks and flows. This condition has an impact on increasing air pollution due to vehicle exhaust gases and decreasing environmental quality. In general, air pollution refers to the release of pollutants into the air that are harmful to the environment and health (Zulauf, N. *et al.* 2019). The travel pattern and traffic volume on the main road sections in the suburbs of Makassar City are presented in *Figure 5*.

This figure shows the difference in vehicle volume at the observation location based on the type of activity that develops on the suburban of Makassar City. The proposed interpretations regarding the traffic volume are: (1) The highest traffic volume occurs at 7.00–8.00 (first peak hour), as many as 15,479 at the business centre and Daya terminal, 12,568 at the PLTU and Sermani industrial power plant locations 11,124 in the Makassar industrial area and 10,479 at the location of Hasanuddin International Airport; (2) The traffic volume at the second peak occurs at 16.00–17.00. In this condition, even though there is a reduction in volume, it will not significantly affect traffic jams on the suburban area; (3) The orientation and destination of

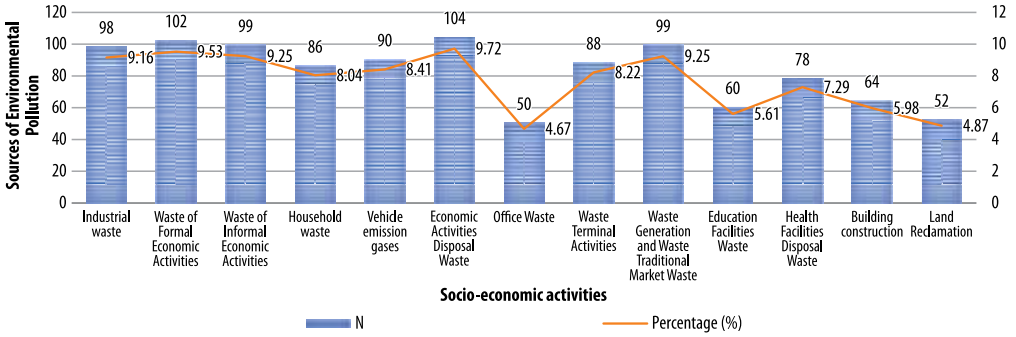

Fig. 4. Decline in the environmental quality of the suburbs of Makassar City. *Source*: Primary data.

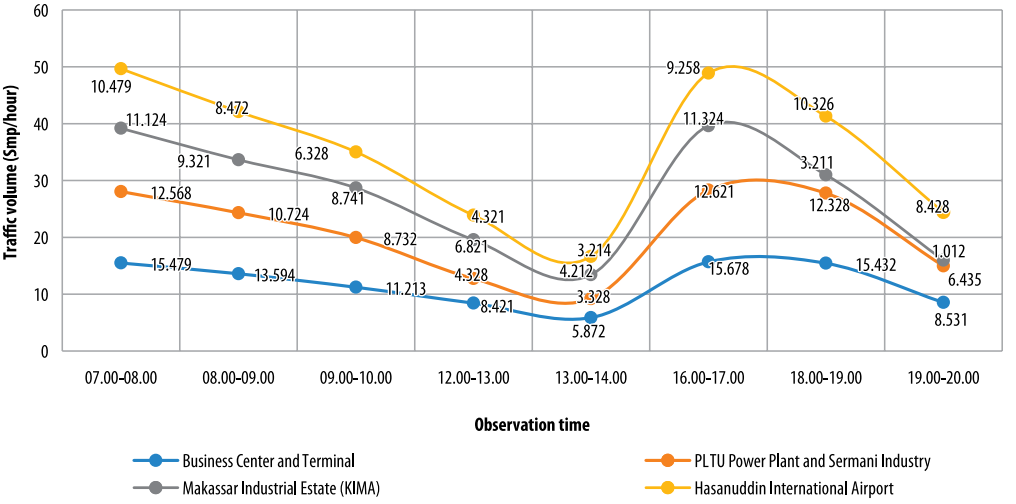

Fig. 5. Traffic volume on the main road corridor in the suburbs of Makassar City. *Source:* Primary data.

transportation movements in the morning are dominated by three main activities, namely offices, education, trade and business centres. Conversely, in the afternoon it is dominated by movement to the area of origin. Increasing traffic is an inherent symptom of vigorous urban development and its prosperity but is concurrently one of the main factors that contribute to the deterioration of the urban environment and the endangerment of the sustainability of urban development (Surya, B. *et al.* 2021c). The mobility of the population from the suburbs to the city centre in relation to the availability of facilities and infrastructure is presented in *Figure 6* showing the mobility of the population in relation to transportation facilities and infrastructure.

Interpretations that can be proposed for these results include: (1) Population mobility in relation to road infrastructure provides an illustration that 60.67 percent is categorized as supportive, 20.67 percent is categorized as

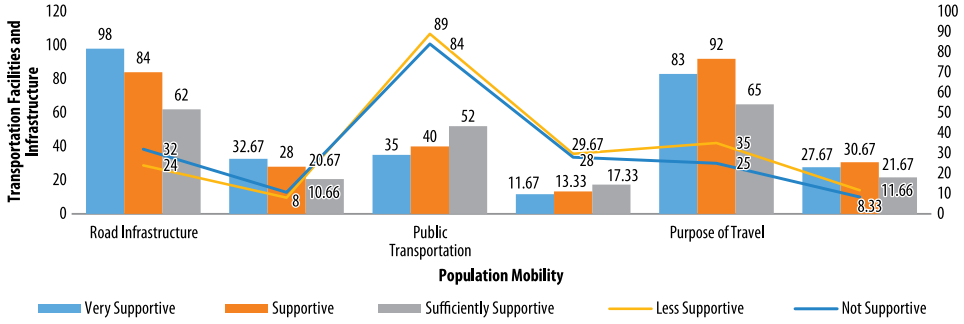

Fig. 6. Population mobility of transportation facilities and infrastructure. *Source*: Primary data.

sufficiently supportive, and 18.66 percent is categorized as not supportive. (2) Population mobility in relation to the availability of public transportation gives an illustration of 25 percent in the supportive category, 17.33 percent in the sufficiently supportive category, and 57.67 percent in the not supportive category. (3) Population mobility in relation to the purpose of the trip gives an overview of 58.34 percent in the supportive category, 21.67 percent in the sufficiently supportive category, and 19.99 percent in the not supportive category. This figure confirms that the mobility of the population from suburban areas to the city centre and vice versa, people tend to use private transportation facilities due to the limitations of public transportation in relation to factors of comfort, security and timeliness to get to their destination. Thus, the function of urban activities and the limitations of public transportation modes lead to dependence on private vehicles in relation to the mobility of residents in suburban areas (Bueno-Suárez, C. and Coq-Huelva, D. 2020).

The facts found in the field illustrate that the increase in socio-economic activities that develop in the suburbs of Makassar City positively associated with land use complexity and transportation system disturbances leading to environmental degradation. The pattern of origin and destination of travel in relation to socio-economic activities in the suburbs of Makassar City is presented in *Figure 7* demonstrating the pattern of origin and destination of travel from the suburbs to the centre of Makassar City.

Interpretations that can be put forward in relation to these results include: (1) Transportation movements related to travel times provide an overview of 21.33 percent with the supportive category, 18.67 percent with the sufficiently supportive category, and 60 percent with the not supporting category. (2) The transportation movement system in relation to movement barriers gives an overview of 25 percent in the supportive category, 22.67 percent in the sufficiently supportive category, and 52.33 percent in the not supportive category. (3) The transportation movement system in relation to the cost of travel obtained an overview of 20.66 percent with the supportive category, 20.67 percent with the sufficiently supportive category, and 58.67 percent with the not supportive category. These results confirm that the travel pattern of the population based on the pattern of origin and destination of movement from the outskirts to the city centre is not effective and efficient in terms of travel time, movement barriers, availability of transportation modes and transportation costs. Thus, travel time, availability of transportation modes and relatively high transportation costs are positively related to the travel pattern of residents from suburban areas to socio-economic activity centres being inefficient and having an impact on increasing air pollution leading to a decrease in environmental quality. The effect of changes in

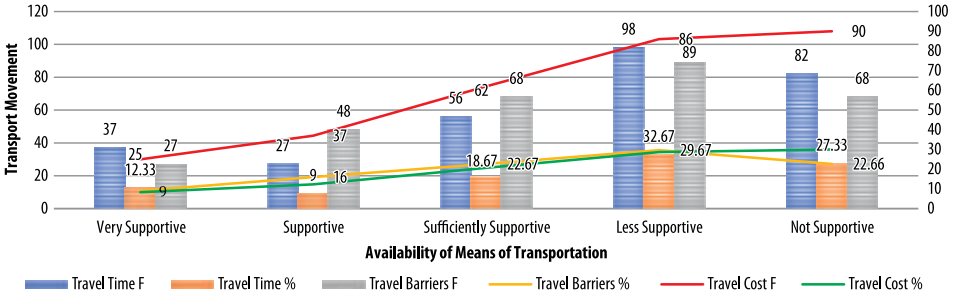

Fig. 7. The pattern of origin and destination of travel from the suburbs to the centre of Makassar City. *Source*: Primary data.

land use, socio-economic activities, population mobility, and transportation system on environmental quality degradation in the suburbs of Makassar City is presented in *Table 2.*

The results of *Table 2* that can be explained include: (1) Changes in land use have a positive effect on the environmental quality degradation; (2) Socio-economic activities have a positive effect on the environmental quality degradation; (3) Population mobility has a positive effect on the environmental quality degradation; (4) The transportation system has a positive effect on the environmental quality degradation. Thus, changes in land use, socio-economic activities, population mobility, and transportation systems simultaneously explain 95.65 percent of the environmental quality degradation in the suburbs of Makassar City. The management model of the urban transportation system and the sustainability of the suburbs of Makassar City is presented in *Figure 8*.

This figure shows a model for estimating land use, population mobility and transportation infrastructure and sustainable development in the suburbs of Makassar City. Interpretations that can be put forward to the model include: First, the variable constructs of land use, population mobility, and transportation infrastructure have a positive effect on

Table 2. Summary of test results for the significance of multiple regression coefficients

Correlation	Coefficient β	Error S_{bi}	t-count	t-table
Land use change to environmental quality degradation (ryx_1)	0.193	0.068	2.972	1.95
Socio-economic activity to environmental quality degradation (ryx_2)	0.148	0.056	2.865	1.95
Population mobility to environmental quality degradation (ryx_3)	0.407	0.098	3.284	1.95
Transportation system to environmental quality degradation (ryx_4)	0.206	0.078	2.893	1.95

Source variant	Sum of squares, JK	Free degrees, db	Average of the sum of the squares, RJK	F-count	F-table $\alpha = 0.05$
Regression	20,642	7	7.548	88.146	6.78
Residue	0,548	12	0.076		
Total	20,642	19	–	–	–

R	R^2	db1	db2	F-count	F-table
0.978	0.9565	7	12	88.146	6.78

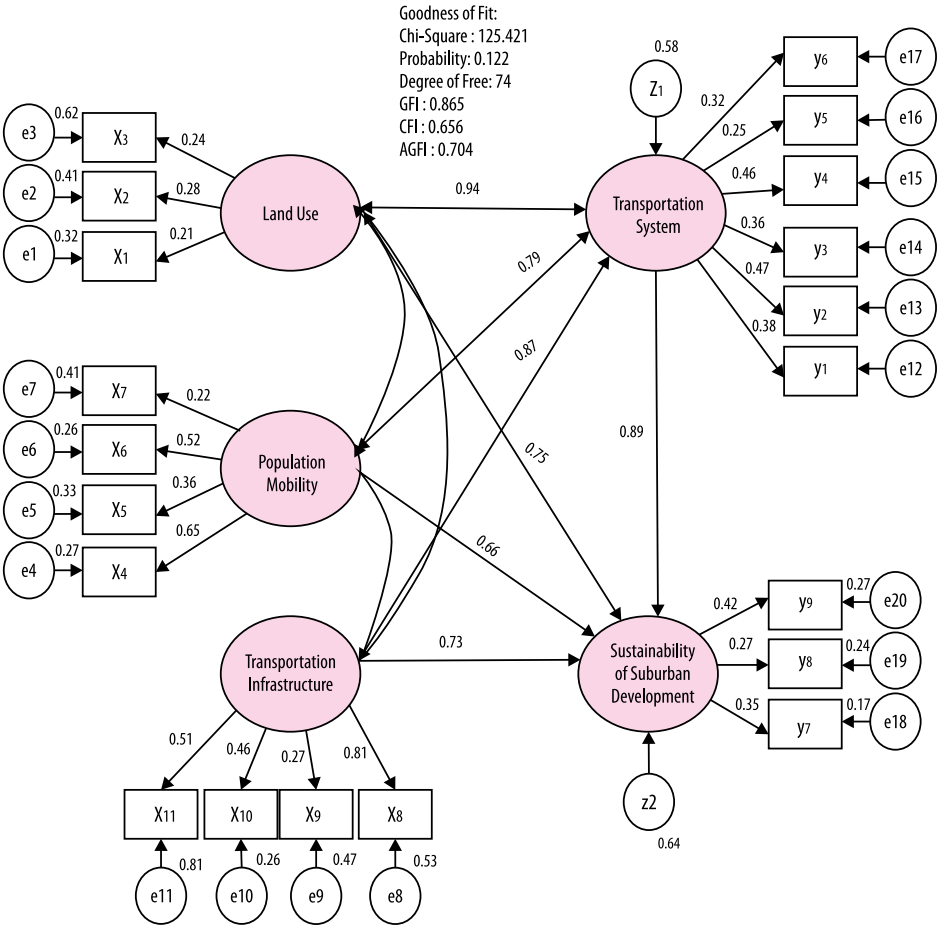

Fig. 8. Urban transportation system model and the sustainability of the suburbs of Makassar City

transportation management and sustainable development of suburban areas of Makassar City. The results of the chi-square test showed a value of 125.421 with a probability of $p = 0.122 > 0.05$, $df = 74$, $GFI = 0.865$, $CFI = 0.656$ and $AGFI = 0.704$. These results confirm that the built model is categorized as a fit model. Second, the total influence of land use on the endogenous variable of transportation management is 0.8836 or 88.36 percent, population mobility on the endogenous variable of transportation management is 0.6241 or 62.41 percent, and transportation infrastructure on the endogenous variable of transportation management is 0, 7569 or 75.69 percent. Third, the total influence of land use on the endogenous variables of suburban development sustainability is 0.5625 or 56.25 percent, population mobility on endogenous variables of suburban development sustainability is 0.4356 or 43.56 percent, transportation infrastructure to endogenous variables the sustainability of suburban area development is 0.5329 or 53.29 percent. The effect of the endogenous variable of transportation management on the endogenous variable of the sustainability of suburban development is 0.7921 or 79.21 percent. Thus, the implementation of the transporta-

tion management model will have an impact on the sustainability of the development of suburbs Makassar City.

Sustainability of the suburbs of Makassar City

The sustainability of the suburban area requires efforts to control the use of space and ensure the balance of the process or condition of a system, in relation to the built environment and biological resources as a single system. This means that the sustainability of the suburbs of Makassar City is part of the effort to ensure the sustainability of the ecosystem in order, to maintain function, productivity and ecological diversity. Five basic principles that can be implemented for the

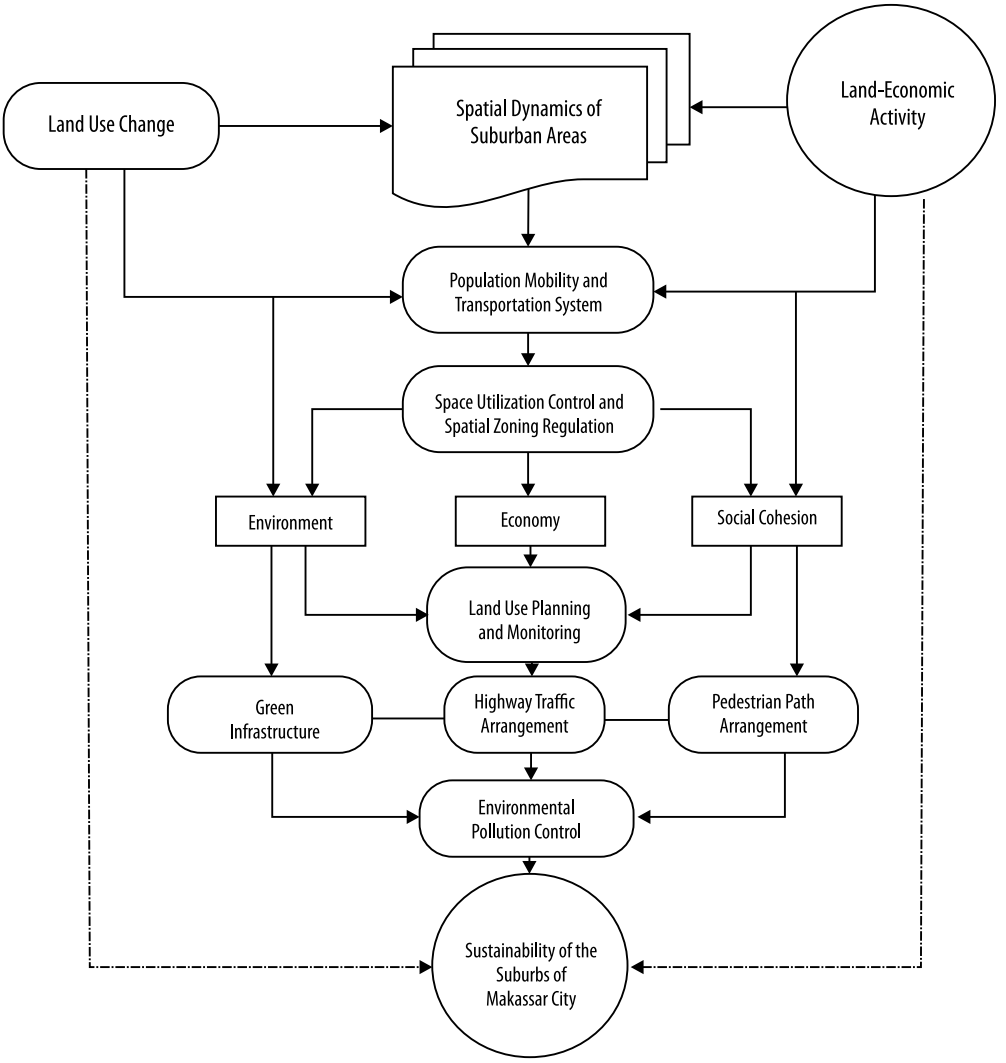

Fig. 9. Sustainability of the suburbs of Makassar City

development of suburban areas towards sustainable development, namely: (1) Capacity, refers to the carrying capacity of the environment as a medium for carrying out community socio-economic activities; (2) Resilience, in terms of interactions between humans and the environment; (3) Adaptive in responding to ecosystem changes; (4) Diversity, in this case integrating the socio-economic interests of the community which is accommodated in a space that does not exceed the carrying capacity of the environment and is integrated with a sustainable transportation movement system; (5) Balance, in this case refers to the balance of the natural environment in relation to the development carried out by the community and the government. This means that the government must take into, account the balance between the expenditure allocated for development activities and the accumulation of human and technological capital to ensure environmental balance towards improving the welfare of the population and the sustainability of the transportation system (Wu, F.C. *et al.* 2020; Surya, B. *et al.* 2020a). The sustainability of the suburbs of Makassar City is presented in *Figure 9*.

Conclusions

The expansion of the Makassar City area has an impact on changes in land use, increased socio-economic activities, population mobility and transportation systems. These three things cause a decrease in the environmental quality of suburban areas. Changes in transportation characteristics coupled with the intensity of land use changes have an impact on air, water and soil pollution. Furthermore, economic activity that tends to increase causes an increase in population mobility based on the pattern of origin and destination of travel and has an impact on increasing traffic volume, slowing vehicles, traffic congestion and high transportation costs. The decline in environmental quality is indicated by the increased potential for environmental pollution due to the intensity of development allocated to suburban areas. Thus, it is necessary to control the use of space, structuring land use and managing the transportation system towards the sustainable development of the suburban area of Makassar City.

The development of the suburbs of Makassar City is oriented to create a balance in the use of natural resources to support sustainable development which is carried out through three main principles, namely (i) future-oriented equality between generations, (ii) the principle of social justice, in terms of fulfilling access and distribution. socio-economic activities towards improving environmental quality, and (iii) responsibility in terms of minimizing environmental impacts and compensating efforts. The implementation of these three principles is realized through controlling the use of space, structuring land use and improving the quality of the environment towards the integration of urban systems.

This study was conducted in a limited scope and only focused on changes in land use, socio-economic activities, population mobility and transportation systems to environmental damage. To complete the results of this study, further research is needed with two main topics, namely: (1) Model of the sustainability of the urban transportation system in suburban areas based on community participation; and (2) Utilization of suburban area space based on the integration of the metropolitan urban system.

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