Surya, Batara; Taibe, Patmawaty; Sariman, Syahrul et al.

Article

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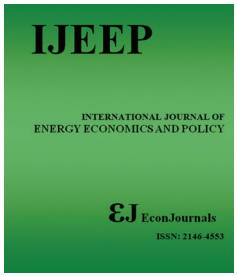
Reference: Surya, Batara/Taibe, Patmawaty et. al. (2023). Renewable energy utilization and environmental pollution control in the New City Area Mamminasata Metropolitan, Indonesia. In: International Journal of Energy Economics and Policy 13 (1), S. 213 - 226. https://econjournals.com/index.php/ijeep/article/download/13723/7129/32078. doi:10.32479/ijeep.13723.



International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2023, 13(1), 213-226.

Renewable Energy Utilization and Environmental Pollution Control in the New City Area Mamminasata Metropolitan, Indonesia

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Received: 09 September 2022 **Accepted:** 27 December 2022 **DOI:** https://doi.org/10.32479/ijeep.13723

ABSTRACT

The dynamics of the development of the Mamminasata Metropolitan new city area has an impact on environmental quality degradation. The increase in development activities causes land use conversion and contributes to an increase in energy demand. This study aims to analyze: The allocation of work space utilization as a determinant of environmental quality degradation in the Mamminasata new city area, the effect of controlling space utilization, renewable energy utilization, and transportation management on improving the environmental quality of the Mamminasata new city area; and formulate a model for the use of renewable energy and the sustainable development of the Mamminasata Metropolitan new city area. This study uses an explanatory sequential approach. Data were obtained through observation, surveys, in-depth interviews, and documentation. The results of the study indicate that the allocation of land for the development needs of socio-economic activities in the new city area has an impact on increasing the burden of pollution on soil, water, and air as well as the complexity of the transportation system in the direction of decreasing environmental quality. Control of space utilization, renewable energy utilization, and transportation management simultaneously have an effect on improving the environmental quality of the Mamminasata new city area with a coefficient of determination of 94.84%. This study recommends the use of renewable energy in supporting socio-economic activities towards the sustainability of the Mamminasata Metropolitan new city area development.

Keywords: New City, Renewable Energy, Environmental Quality, Sustainable Development
JEL Classifications: Q47, Q2, Q01

1. INTRODUCTION

Urbanization in the dynamics of urban development, in addition to having an impact on increasing population, also contributes to the increase in the need for housing and settlements as well as increasing the fulfillment of facilities and infrastructure needs. Increasing population contributes to environmental degradation, climate change and sustainable development (Surya et al., 2020; Gyau and Abdulai, 2001; Surya et al., 2021). Urban urbanization in Indonesia has an impact on population density and in particular on large and metropolitan cities. Furthermore, the development of a metropolitan area is basically aimed at improving the quality of life of its population through the support of job creation and urban service systems (Buchori et al., 2021; Surya et al., 2021).

The development of the new metropolitan city area is an effort made to meet the needs of the population for housing, facilities and infrastructure as well as service infrastructure (Salazar et al., 2021). Controlling environmental pollution in the new city area will require efforts to optimize the use of renewable energy (Surya et al., 2021; Zahedi et al., 2022). Furthermore, the potential for renewable energy that can be utilized to support the development of the new city area of Metropolitan Mamminasata, namely water energy, wind energy, solar energy, and biomass.

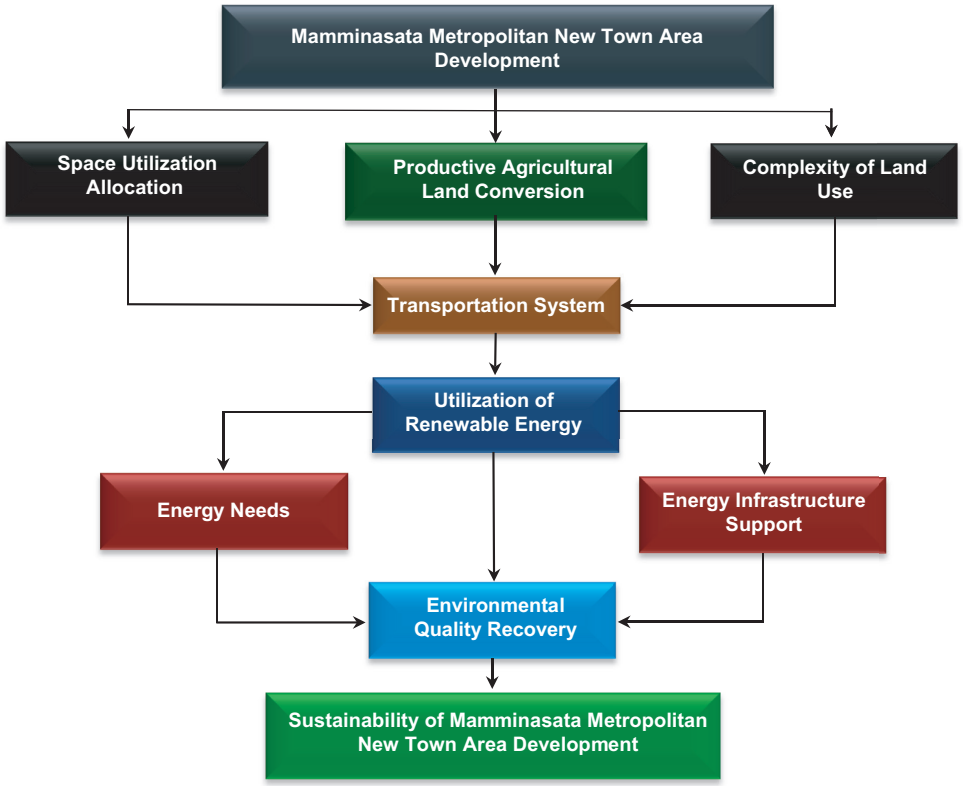
The acceleration of the development of the Mamminasata Metropolitan new city area is marked by changes in land use and the complexity of the transportation system. This condition shows that urban policies implemented by the government contribute to the decline in the quality of the environment and transportation system (Al-Hinkawi et al., 2021; Surya et al., 2021). Furthermore, the socio-economic activities developed have an impact on changes in land cover and changes in the characteristics of the urban environment. It is necessary to control and restore environmental quality in relation to the activities developed (Kelly-Fair et al., 2022). Furthermore, changes in the environmental characteristics of the new city area are marked by the use of water catchment areas, land reclamation, and a decrease in the carrying capacity of the environment. Thus, it is necessary to assess the carrying capacity of the environment in order to support the sustainability of the development of new city areas in a comprehensive manner (Xu et al., 2020). This means that it is very important to restore the environmental quality of the new city area to be synergized with the use of renewable energy (Surya et al., 2021).

The challenge of developing the Mamminasata Metropolitan new city area is how to integrate the urban system towards improving environmental quality, controlling space utilization and sustainable development. Furthermore, the direction of development of the new urban areas of Metro Tanjung Bunga, Moncongloe, and Pattalassang is dominantly developed to accommodate various urban activities, including: (1) Recreational facilities with additional land area of 129 ha; (2) The construction of housing and settlements occupies an area of 5,133.50 ha; (3) Trading and commercial activities 889.14 ha to 27.42 ha; (4) Office facilities occupy an area of 11.20 ha; (5) Educational facilities occupy an area of 20.75 ha; and (6) Health facilities occupy an area of 8.9 ha. The tendency of land use conversion from time to time causes a decrease in environmental quality, the complexity of spatial use, the developing dualistic economic system and the complexity of the metropolitan urban transportation system. The complexity of the spatial use of the new urban area is marked by the conversion of productive agricultural land towards changes in the characteristics of the surrounding rural areas (Pratomo et al., 2020; Surya et al., 2020). This means that the acceleration of the Maminasata Metropolitan urban development will require support for the use of renewable energy which is synergized with increasing the productivity of the community's economic business. Furthermore, the development of new urban areas is contextualized in three main things, namely (i) environmental sustainability, (ii) economic sustainability, and (iii) social sustainability. Thus, the direction of new city development was created to support the community's creative and sustainable economy (Surya et al., 2021; Betlej and Kaˇcerauskas, 2021).

Environmental quality improvement based on the use of renewable energy is developed by referring to three main principles, namely (i) ensuring the sustainability of natural resources to remain sustainable, (ii) ensuring the supply of energy needs that tend to increase, and (iii) ensuring the needs of future generations. These three principles are used as the basis for ensuring ecosystem stability and environmental sustainability in the Mamminasata Metropolitan new city area. Furthermore, the potential for renewable energy that can be utilized to support the development of the Mamminasata Metropolitan new city area, among others: (1) Water energy sourced from the Jenneberang watershed with a capacity of 2,240 m^3/s, Karangloe dam with a capacity of 40.53 m3/second, and potential Maros river watershed with a usable water flow of 16.85 m^3/s. The potential of water energy allows it to be converted into electrical energy and produced continuously for 24 h/day; (2) Biomass as an energy source that can be optimized for use in the Mamminasata Metropolitan City, namely forest products, agro-industrial waste, and urban waste. Potential energy that can be utilized, namely 62,645,460 Kwh in urban areas of Takalar Regency, 381,593,201 in urban areas of Gowa Regency, and 9,035,201 in urban areas of Maros Regency; (3) The potential of solar energy that can be utilized to support the development of the new city area of Metropolitan Mamminasata is developed towards the fulfillment of long-term electrical energy and household needs by using solar panels; and (4) Wind power is a renewable energy source through the use of windmills to be converted into electrical energy of 100 MW to meet the needs for the development of socio-economic activities in the new city area. Optimizing the use of renewable energy will support the restoration of environmental quality and support the fulfillment of energy for developed urban activities (Pai and Senjyu, 2022; He et al., 2022).

The urgency of this study is contextualized in three things, namely: (1) The use of renewable energy is aimed at supporting the restoration of the environmental quality of the Mamminasata new city area; (2) Controlling the use of space through the preparation of green open space is aimed at ensuring environmental stability and balance; and (3) The integration of the urban system through the use of renewable energy is aimed at supporting the sustainable development of the Mamminasata new city area. Thus, this study is focused on answering the research questions: (1) How does the allocation of spatial use work as a determinant of environmental quality degradation in the Mamminasata new city area? (2) How big an influence does space utilization control, renewable energy utilization, and transportation management have on improving the environmental quality of the Mamminasata new city area? and (3) What is the model for the use of renewable energy and the sustainable development of the Mamminasata new city area? Furthermore, the benefits of this study include: (1) Assisting the government in formulating policies for the development of the new Mamminasata Metropolitan area; (2) A reference in formulating a policy to restore the environmental quality of the new city area; and (3) A reference in formulating the sustainability of

Figure 1: Conceptual framework for the development of the Mamminasata Metropolitan new city area



Source: Author's elaboration

the new city area development of Metropolitan Mamminasata. The conceptual framework of this study is presented in Figure 1.

2. MATERIALS AND METHODS

This study uses an explanatory sequential quantitative-qualitative approach. Quantitative data obtained through surveys and documentation. While qualitative data obtained through observation and in-depth interviews. Case studies are selected in the research with the following considerations: (1) The characteristics of the case are specific; (2) Realities that develop in the field are complex; and (3) The allocation for the development of new urban areas has an impact on environmental quality degradation. Furthermore, a combination of explanatory quantitative-qualitative approaches is presented in Figure 2.

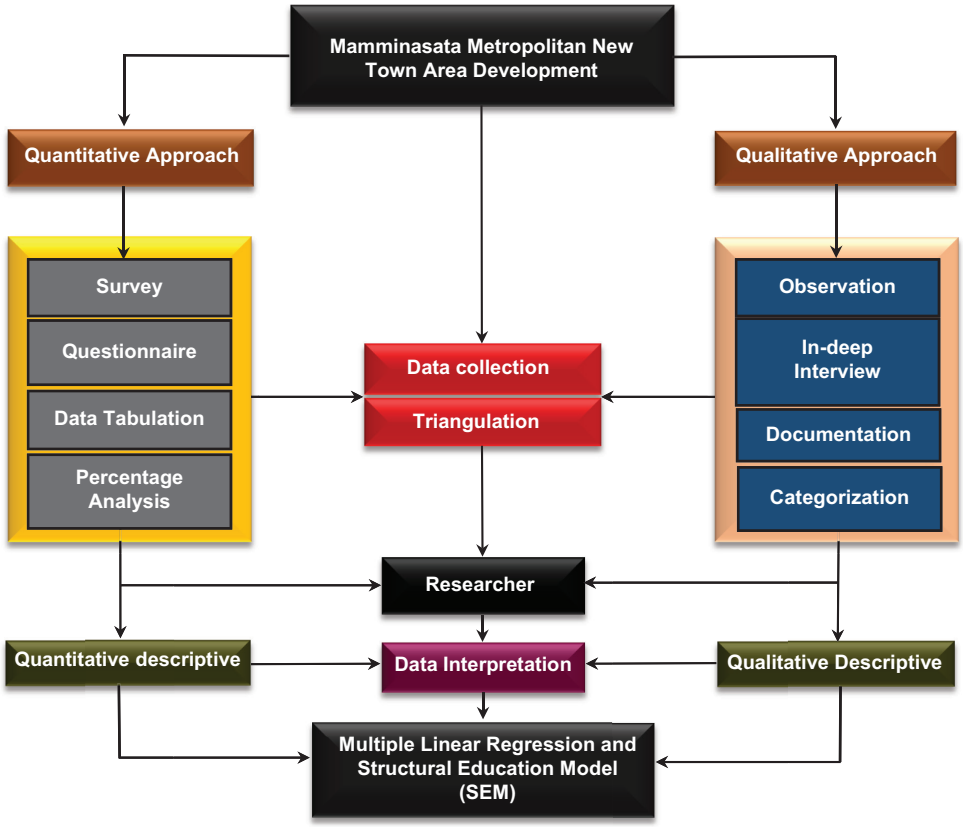
2.1. Study Area

This research was carried out at three locations in the new city area of Metropolitan Mamminasata. This study was conducted from January to July 2022. The selection of research locations was based on the following considerations: (1) The allocation of space utilization for the newly developed city area requires support for the use of renewable energy; (2) Increasing housing and settlement development activities as well as infrastructure development support have an impact on the intensity of land use conversion and environmental degradation; (3) The environmental management of the new city area has not been optimal in supporting the sustainability of the Mamminasata Metropolitan urban system; and (4) Changes in land use in urban areas have an impact on the complexity of ecosystems and transportation movement systems based on patterns of origin and destination of movement. The research location of the Mamminasata Metropolitan new city area is presented in Figure 3.

2.2. Method of Collecting Data

The collection methods in this study are divided into two categories, namely (1) Primary data, obtained through observation, surveys, and in-depth interviews; and (2) secondary data, obtained through the relevant agencies and institutions related to the study of the development of the new urban area of Metropolitan Mamminasata. transportation based on the origin and destination of the trip, and (iii) the environmental characteristics of the new city area. The instruments used in the observation are (i) field notes, (ii) periodic notes, and (iii) checklists. In-depth interviews in this study were used to search data, namely (i) the characteristics of the residents of the new city area, (ii) the factors causing the decline in environmental quality, (iii) the mobility of goods and passengers, and (iv) the role of the community in the use of renewable energy. The tools used in in-depth interviews, namely tape recorders, pictures, and interview guides equipped with loose notes, checklists, and score scales. Questionnaires in this study were used to track data, including: (1) Renewable energy utilization, measured by indicators, namely type of energy, energy distribution, and energy demand; (2) Control of space utilization, measured by indicators, namely the licensing system, provision of green open space, space utilization ratio, and policy implementation; (3) Transportation management is measured by indicators, namely the availability of transportation, mode of transportation, convenience, and travel time; and (4) The sustainability of the development of new urban areas is measured by indicators,

Figure 2: Combination of explanatory sequential quantitative-qualitative approach



Source: Author's elaboration

namely environmental sustainability, economic sustainability, and social sustainability. The results of the data obtained through the questionnaire were then measured using an ordinal scale. The measurement of the questionnaire data in this study uses scoring numbers, namely (i) a score of 5 for the very fulfilling category, (ii) 4 for the fulfilling category, (iii) 3 for the moderately fulfilling category, (iv) 2 for the less fulfilling category, and (v) a value of 1 for the category not fulfilling category. Furthermore, the documentation data in this study, among others: (1) The Mater plan for the new city area of Metropolitan Mamminasata was obtained through the Department of Human Settlements and Spatial Planning of the Province of South Sulawesi; (2) Data on the population of the new city area is obtained through the Central Statistics Agency of South Sulawesi Province; and (3) Data for the new city development policy of Metropolitan Mamminasata is obtained through the Regional Development Planning Agency of South Sulawesi Province.

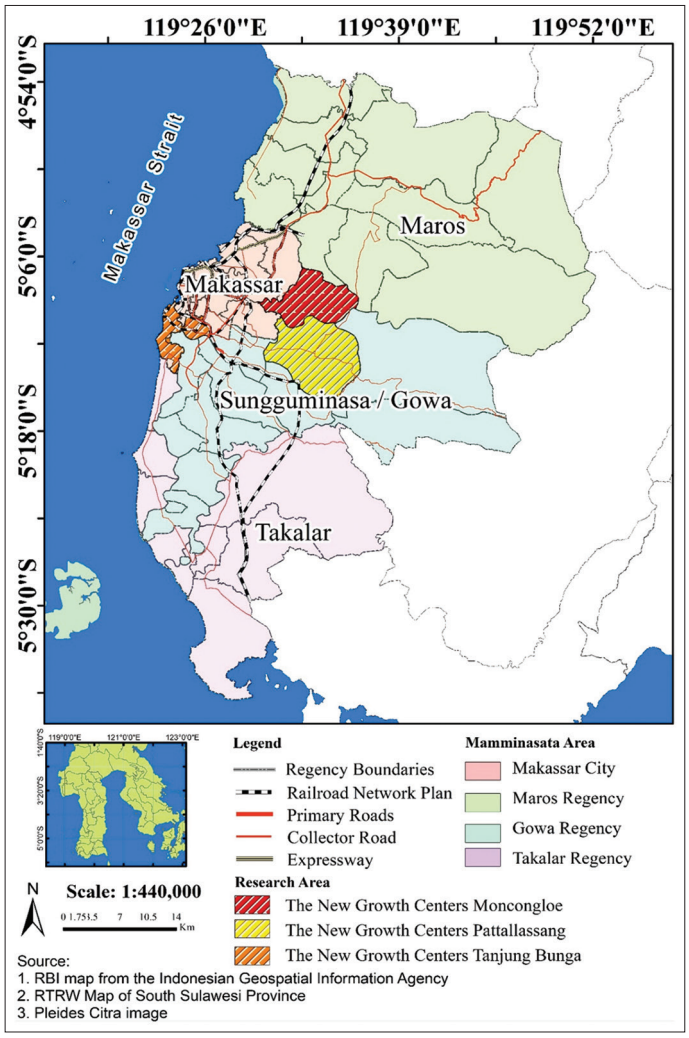
2.3. Research Informants and Respondents

Qualitative data in this study were obtained through informants. Informants were determined using the snowball method. That is, the researcher determines the actors who will be interviewed based on information obtained from the government that is implementing the construction of the Mamminasata Metropolitan new city area. Furthermore, the determination of key informants was selected with the following considerations: (i) able to provide good information about the implementation of development, and (ii) being directly involved in the implementation of new city development. The key informants that have been determined by the research are then used to obtain information on other informants who can be interviewed based on the required data needs. The aim is to obtain the same information and picture related to the implementation of the new urban area development of Metropolitan Mamminasata. Furthermore, in order to obtain more in-depth information, several respondents who have been determined are also selected as informants.

The number of informants in this study was set at 16 people, 10 informants were selected based on information obtained from the local government and 6 people came from respondents. The six informants sourced from respondents were determined based on the following criteria: (1) Local government who understands the implementation of new urban area development; (2) Communities who are directly involved in the development of new urban areas; (3) Able to provide good information about the implementation of new urban area development; and (4) Able to provide good information about the area developed in the implementation of the new urban area development of Metropolitan Mamminasata. Furthermore, the snowball method used in determining the informants in this study is presented in Figure 4.

Data entry through respondents in this study was guided by researchers and enumerators. Questionnaires were distributed to three locations in the new city area of Metropolitan Mamminasata. The criteria for the actors who fill out the questionnaire (respondents), are (i) the people who inhabit the new city area, (ii) the local government, (iii) the developers who carry out the construction, and (iv) the people who use public transportation and

Figure 3: The research location of the Mamminasata Metropolitan new city area



private transportation. Furthermore, the enumerators in this study were selected with the following considerations: (1) Having the ability to collect data; and (2) Understanding the characteristics, social situation, and behavior of the community. Furthermore, the research sample was determined using the purposive sampling method which was determined by the researcher with certain considerations. The sampling measurement technique refers to Cochran (1991). The formulation used in determining the number of samples is as follows:

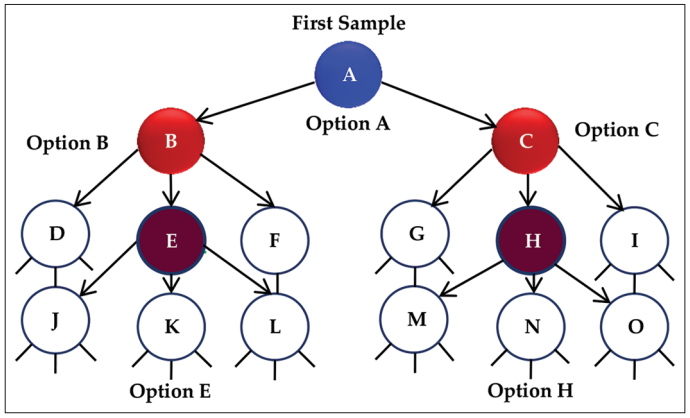
$$n = \frac{Z^2 pq}{e^2}$$

where n is the number of samples required, Z^2 is the value in the normal curve for a deviation of 5% with a value = 1.96, p represents a 50% probability of being correct (0.5), q represents a 50% probability of being wrong (0.5), and e is the level of sample error in the study using 5% of the 95% confidence level. Furthermore, the number of samples was set to 400 respondents.

2.4. Data Analisys Method

Qualitative analysis in this study refers to the results of the data obtained through observations, in-depth interviews, and

Figure 4: Schematic of the snowball sampling technique



documentation. The data were analyzed in three ways, namely data reduction, data display, and conclusion. The process is carried out by separating information into categories based on the views of the informants and the facts found in the field. Furthermore, the stages of qualitative analysis carried out include: (i) domain analysis, in this case based on observed behavior includes; place, actor, and activity, (ii) taxonomic analysis, in this case the use of space is a defined domain to be described in detail. That is, the allocation of space utilization is studied in depth as a determining factor for the decline in the environmental quality of the new city area. The aim is to find the factors that cause environmental degradation, the complexity of the transportation system and the sustainability of the development of the Mamminasata new city area, (iii) componential analysis is carried out by contrasting field conditions which show specific differences based on the characteristics of the location of the new city area which is currently this was developed, and (iv) analysis of cultural themes was carried out by integrating across domains found in the field. The aim is to explain the causes of the decline in environmental quality and the efforts that can be made to support the restoration of environmental quality and the sustainable development of the Mamminasata Metropolitan new city area.

Quantitative analysis in this study uses multiple linear regression and structural education model (SEM) methods. Multiple linear regression analysis was used to test the effect of variable X_1 (space utilization control), X_2 (use of renewable energy), X_3 (transportation management), to the variable "Y" (environmental quality improvement). Multiple regression analysis using the following formulation:

$$Y = a + b_1X_1 + b_2X_2 + b_3X_3 \ldots\ldots b_kX_k + e$$

$$a = \frac{(\sum Y) - (b_1 \text{ x} \sum X1) - (b_2 \text{ x} \sum X2)}{n}$$

$$b_1 = \frac{[(\sum X_2{}^2 \text{ x} \sum X_1y) - (\sum X_2y \text{ x} \sum X_1X_2)}{[(\sum X_1{}^2 \text{ x} \sum X_2{}^2) - (\sum X_1 \text{ x} \sum X_2)^2]}$$

$$b_2 = \frac{[(\sum X_1{}^2 \text{ x} \sum X_2y) - (\sum X_1y \text{ x} \sum X_1X2)}{[(\sum X_1{}^2 \text{ x} \sum X_2{}^2) - (\sum X_1 \text{ x} \sum X_2)^2]}$$

$$r^2=\frac{(b_1 \text{ x} \sum X_1 y) + (b_2 \text{ x} \sum X_2 y)}{\sum y^2}$$

$$r=\sqrt{r^2} =\frac{\sqrt{(b_1 \text{ x} \sum X_1 y) + (b_2 \text{ x} \sum X_2 y)}}{\sum y^2}$$

Where Y is the dependent variable, a, b_1, b_2, b_3,……, b_k is the regression coefficient, X_1, X_2, X_3,……, X_k is the independent variable, and e is the confounding error, meaning the values of other variables that are not included in the equation. Furthermore, r^2 is the coefficient of determination which shows the effect of the variable X_1, X_2 and X_3 to variable Y, under the condition: (1) If r^2 worth 0, then in the regression equation model that is formed, in this case the variation of the dependent variable Y cannot be explained at all by the variation of the independent variable X_1 and X_2; (2) If r^2 worth 1, then the regression equation model that is formed, in this case the dependent variable Y can be perfectly explained by the variation of the independent variable X_1 and X_2. Furthermore, in order to find out how big the correlation is between the variables simultaneously X_1, X_2, X_3., X_k to variable Y, using multiple correlation coefficients, provided that: Value r: $-1 \leq r \leq +1$. If the value of r is close to the value of + 1 or –1, then it can be said that the stronger the relationship/correlation that occurs, on the contrary, if the value of r approaches 0, the weaker the relationship/correlation that occurs.

Structural education model (SEM) in this study is used to build a model based on predetermined variables, including: (1) The construct of exogenous space use variables is measured by land use allocation indicators (X_1) with sub indicators, namely housing and settlements, commercial, social activities, and infrastructure. (2) Exogenous variable construct of renewable energy utilization (X_2) measured by indicators, namely the type of energy, energy distribution, and energy demand. (3) Construct of exogenous variables controlling space utilization (X_3), measured by indicators, namely the licensing system, provision of green open space, space utilization ratio, and policy implementation. (4) Transport management exogenous variable construct (X_4), measured by indicators, namely the availability of transportation, mode of transportation, comfort, and travel time. (5) The exogenous variable construct of improving environmental quality is measured by indicators, namely environmental quality recovery, water quality index, air quality index, and land cover index. Furthermore, endogenous latent variables, environmental quality (y_1) with sub-indicators of pollution levels, air quality, water quality, and land cover (ii) the latent variable of the sustainability of the new city area is measured by indicators, namely environmental sustainability (y_2) with sub-indicators of air pollution, water pollution, and land cover changes, economic sustainability (y_3) with sub-indicators of job availability, economic growth, and utilization of natural resources that ensure intergenerational needs, socio-cultural sustainability (y_4) with sub-indicators of local wisdom, social networks, and social justice. The SEM analysis method uses the following formulation:

$$\eta=\alpha+B_\eta+\Gamma\xi+\zeta$$

$$\eta-B_\eta=\alpha+\Gamma\xi+\zeta$$

$$(I-B)_\eta=\alpha+\Gamma\xi+\zeta$$

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

Where α is the intercept vector, B and Γ is the coefficient matrix and $\zeta = \zeta_1\ \zeta_2\ \zeta_m$ 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 $m \times 1$, η is the endogenous latent variable $m \times 1$, B is the coefficient matrix of the endogenous latent variable $m \times m$, Γ is the coefficient matrix of the exogenous latent variable $m \times n$, ξ is the exogenous latent variable vector $n \times 1$, ζ structural model error vector relationship between η and ξ size $m \times 1$. Furthermore, random vector η and ξ not measured directly but through the indicator, namely the variable $Y^T = (y_1, y_2,\ldots\ldots y_p)$ and $X^T = (X_1, X_2,\ldots. X_p)$. The measurement model uses the following formulation:

$$df=\frac{p+q+1}{2}=t$$

$$\text{RMSEA}=\frac{F_0}{df} \text{ or } F0 = \max F = \frac{df}{n-1}$$

$$\text{AGFI} = 1-\frac{df_0}{df_h}\ 1-\text{GFI}$$

$$\text{GFI} = 1-\frac{FS}{FS}$$

Where df_0 is the degrees of freedom When there is a hypothesized model, df_h is the degrees of freedom for the hypothesized model. $FS\sum\theta$ is the minimum value of the function F for the hypothesized model, $FS\sum\theta$ is the minimum value of the function F when no model is hypothesized. GFI values are in the range from 0 to 1, and higher values are categorized as better. Furthermore, the Root Mean Square Error of Approximation (RMSEA) is the degree of fit used to measure the proximity of a model to the population. Then, AGFI is an extension of GFI which is used to compare the proposed model with the basic model. If the RMSEA value is ≤ 0.05 then the model is appropriate, and if the AGFI value ranges from 0 to 1 and the AGFI ≥ 0.90 shows good fit while $0.80 \leq$ AGFI < 0.90 showing marginal fit.

3. RESULTS AND DISCUSSION

3.1. Determinants of New City Area Development and Environmental Quality Decline

The new city area of Metropolitan Mamminasata which was developed to accommodate the need for housing, facilities and infrastructure due to the increase in population which is increasing every year. This means that spatial planning policies are developed to meet the target of fulfilling housing needs and other supporting activities as an integral part of the metropolitan urban system (Claassens and Koomen, 2020; Mharzi Alaoui et al., 2022).

Furthermore, the orientation of the development of new urban areas which is dominant to fulfill housing and settlement needs as well as support for completeness of facilities and infrastructure has an impact on changes in land use and utilization of water catchment areas. Fulfillment of needs basically affects the scarcity of land (reflected by the increase in land prices) and the increase in inefficiency of land use and its effect on the carrying capacity of the environment (Getzner and Kadi, 2020; Wang 2022). Thus, changes in land use and the complexity of spatial use due to the development of new urban areas have an impact on environmental quality degradation (Yang et al., 2020; Zhang, et al., 2022). The spatial utilization of the Mamminasata new city area is presented in Table 1.

Interpretations that can be put forward to (Table 1) include: First, the new city area of Metropolitan Mamminasata is developed to meet the needs of large-scale housing and settlement development by utilizing productive agricultural land. The development of housing and infrastructure in urban areas has a direct influence on changes in forest cover, land use conversion, and environmental degradation. The intensity of land use change will affect urban resilience and decrease environmental quality in the direction of landscape diversity, increase in surface temperature, and the availability of green open spaces (Dennis et al., 2019; Surya et al., 2021; Ortiz et al., 2022). Changes in the use of space in the new city area are marked by the use of water catchment areas, coastal border areas and river borders. Thus, land use management efforts are needed towards optimizing watersheds, coastal areas, and strictly regulating the use of water catchment areas in the direction of restoring environmental quality (Liu et al., 2022; Grabowski et al., 2022; Teston et al., 2022). Facts found in the field show that an increase in housing, service, commercial and infrastructure development activities contributes positively to an increase in water quality pollution and land cover changes. That is, an increase in the number of urban residents towards the development of new urban areas has an effect on spatial pressure and affects the use of watersheds and changes in land cover in coastal areas towards water quality pollution (Syafri et al., 2020; Surya et al., 2020; Yokosawa and Mizunoya, 2022; Brontowiyono et al., 2022). Furthermore, development activities that tend to increase in addition to causing a high pollution load also have an impact on the destruction of mangrove forest habitat due to coastal reclamation. This means that mangrove forest rehabilitation is needed in relation to the provision of social, economic, and environmental services to help reduce carbon dioxide concentrations and control sediments (Rudianto et al., 2020; Arifanti et al., 2022). Implications that can be directly observed in coastal areas due to the addition of land for the development needs of new urban areas and socio-economic activities have an impact on the potential threat of roof flooding due to sea level rise. Thus, it is necessary to anticipate climate change and control floods due to anthropogenic pressure which causes an increase in watertight surfaces and potential vulnerability to natural disasters in coastal areas (Čepienė et al., 2022; Barbaro et al., 2022).

Second, the change in land use in the new city area is closely related to the implementation of the South Sulawesi provincial government policy towards the urban spatial integration of the Mamminasata Metropolitan. That is, the main driving factor for land use change is human activity guided by policies and the degree of land use change is positively correlated with the level of regional, social and economic development (Zheng et al., 2022; Kurnia et al., 2022). The urban spatial integration has an impact on population mobility and its effect on increasing the flow of goods and passengers transport. Spatial integration has an impact on population mobility services based on information and communication technology in relation to socio-economic conditions, urban forms, and culture (Tarnovetckaia and Mostofi, 2022; Che et al., 2022). Thus, the pattern of population mobility from the direction of new urban areas to activity centers which tends to increase over time has an impact on the complexity of the Mamminasata Metropolitan urban transportation system. The pattern of population mobility is closely related to work, shopping, and social relations based on distance and spatial distribution (Alhazzani et al., 2021; Macedo et al., 2022). The facts found in the field indicate that the pattern of origin and destination of people's journeys has an impact on traffic congestion and an increase in the burden of air pollution originating from motor vehicle exhaust gases. Thus, an effective travel demand management strategy is needed to reduce traffic congestion and improve environmental

Table 1: Spatial use of the Mamminasata Metropolitan new city area

Land use	Mamminasata metropolitan new city area					
	Metro tanjung bunga		Moncongloe		Pattalassang	
	Land area (ha)	%	Land area (ha)	%	Land area (ha)	%
Mixed garden	11.20	0.4	32.1	1.4	128,5	7.3
Empty land	160	6.4	194.5	9.3	312,7	17.8
Production forest	-	-	290.3	13.9	15.8	0.9
Catchment area	2.5	0.1	49.1	2.4	13.5	0.8
Ricefield	37.7	1.5	133.8	6.4	134,6	7.7
Pool	2.5	0.1	15.1	0.7	12.7	0.7
Services	25.8	1.0	12.7	0.6	4.3	0.2
Medical facility	5.9	0.2	2.1	0.1	2.6	0.1
Educational facilities	6.7	0.3	5.3	0.3	3.1	0.2
Commercial	25.9	1.0	24.1	1.2	6.7	0.4
Place of worship	2.5	0.1	2.0	0.1	5.5	0.3
Office facilities	7.2	0.3	1.7	0.1	2.1	0.1
Recreational facilities	31.7	1.3	-	-	-	-
Housing and settlements	2,177,3	87.3	1,325,2	63.5	1,114,3	63.5

Source: Mamminasata Metropolitan Spatial Planning, 2005-2025

conditions due to pollution loads that tend to increase due to additional socio-economic activities (Baghestani et al., 2021; Liu, 2021). Third, the allocation of space utilization which tends to increase along with the complexity of the transportation system is positively associated with environmental degradation. Facts found in the field show that the development of the Mamminasata Metropolitan new city area has a tendency to continue to increase and the triggering factor is the increase in population and the flow of development investment (Stone et al., 2019; Bamrungkhul and Tanaka, 2022). Sources of environmental pollution in the new city area are presented in Figure 5.

Figure 5 shows the sources of environmental pollution in the new city area of Metropolitan Mamminasata. Interpretations that can be proposed include: (1) The highest environmental pollution is contributed by building construction or 13.26%; (2) The development pattern using the land clearing method contributed 11.88%; (3) The development of new city areas through coastal reclamation contributes 11.55%; (4) The volume of traffic generated by motor vehicle exhaust gas contributes 11.45%; and (5) Conversion of productive agricultural land carried out through land reclamation contributed 10.82%. These results confirm that the increase in development activities that tend to increase from time to time has an impact on increasing the burden of environmental pollution in the direction of ecosystem imbalance. Thus, it is very important to anticipate climate change and adapt to natural disaster mitigation which is integrated with improving the quality of the environment and human development (Li and Xu, 2021; Reed et al., 2022). The facts found in the field illustrate that very intensive development activities are accompanied by conversion of agricultural land, utilization of water catchment areas, low public awareness, and high population mobility to activity centers and environmental imbalance due to limited open space and its impact on environmental degradation in the Mamminasata Metropolitan new city area.

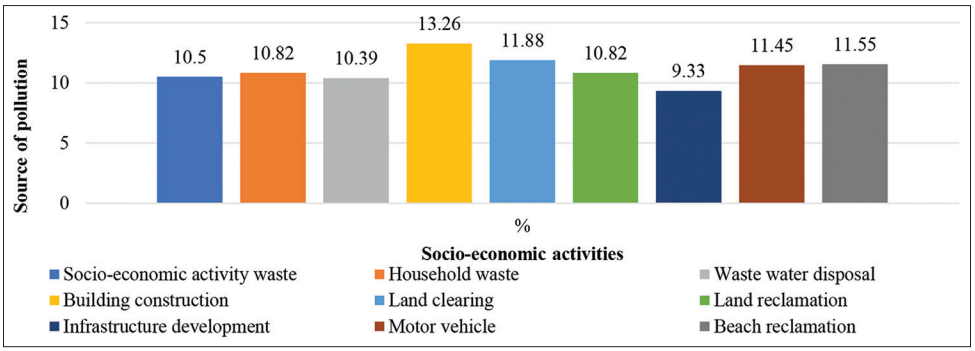
3.2. Transportation System and Environmental Pollution Control

The development of the new city area contributes directly to the movement system of urban transportation services for the Mamminasata Metropolitan City based on the pattern of origin and destination of the trip. The expansion of urban areas through the development of new urban areas has a tendency towards long-distance travel patterns so that, it has a direct effect on the transportation movement system, traffic congestion, and the burden of air pollution (Zhao et al., 2010; Graells-Garrido et al., 2021). Furthermore, the pattern of people's journeys to the centers of socio-economic activity is dominant using private transportation facilities, when compared to the use of public transportation modes. This means that the mobility of goods and passengers which tends to increase every year contributes to the increase in emissions released by motorized vehicles, namely Carbon Monoxide (CO), Hydrocarbons (HC), Nitrogen Oxides (NO), and dust (Uhereka et al., 2010; Vélez and Plepys, 2021). The pattern of people traveling from the new city area to the centers of socio-economic activity is presented in Figure 6 and the traffic volume on the main urban road section of the Mamminasata Metropolitan is presented in Figure 7.

Figure 6 shows the pattern of people traveling from the location of the new city area to the centers of socio-economic activity. Interpretations that can be put forward include: (1) The intensity of the pattern of origin and destination of the trip, in addition to having an impact on increasing traffic volume, also contributes to traffic congestion; (2) The dominant use of motor vehicle materials, namely gasoline, pertamax, premium, pertalite, and diesel fuel has an impact on decreasing air quality sourced from motor vehicle exhaust gases; and (3) The increase in exhaust gas from motor vehicles that use low-quality fuel oil has an impact on increasing air pollutant gases, namely carbon monoxide (CO), hydrocarbon compounds (HC), nitrogen oxides (NOx), sulfur oxides (SOx), and matter particulate (PM) dust including lead (Pb). These results confirm that the increase in pollutant gases that tend to increase has an impact on public health problems, in this case diseases of the respiratory tract and cause systemic effects of toxins. This means that vehicle exhaust gas originating from the use of fuel oil with high sulfur content is one of the causes of acid rain, a greenhouse gas that results in global warming and triggers global climate change (Ali et al., 2020; Ogunkunle and Ahmed, 2021; Giechaskiel et al., 2022). Furthermore, the traffic volume on the main urban road section of the Mamminasata Metropolitan is presented in Figure 7.

Figure 7 shows the pattern of people traveling from the new city area to the centers of socio-economic activity. Interpretations that can be put forward to these results include: (1) The journey of the population to the destination area is related to the dominant traffic volume, which is influenced by the movement towards

Figure 5: Potential and sources of environmental pollution in the Mamminasata Metropolitan new city area



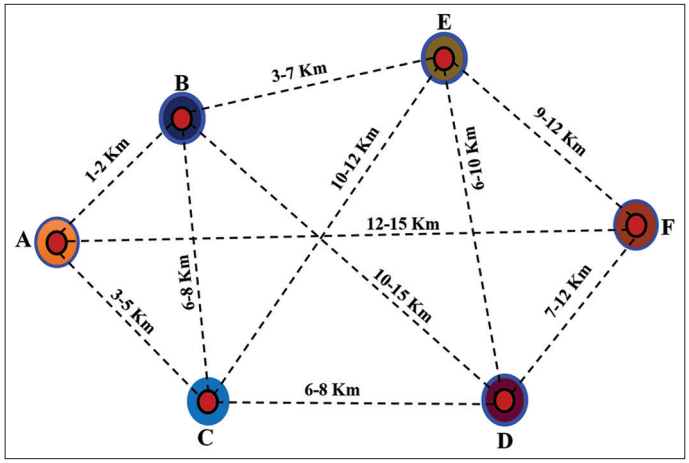
Source: Primary data

educational, commercial, and tourism activities; and (2) the traffic volume which tends to increase in addition to having an impact on congestion and air quality pollution also affects the generation and attraction of the urban transportation system. These results confirm that the management of the urban transportation system based on the origin and destination of people's journeys is less effective and efficient. Thus, the travel orientation of residents from the new city area to the centers of socio-economic activity will experience obstacles in terms of security, comfort, and timeliness to the destination area (Yusoff, et al., 2021; Raza et al., 2022).

3.3. Control of Space Utilization and Utilization of Renewable Energy

The allocation of spatial use for the new city area of Metropolitan Mamminasata which tends to increase from time to time contributes positively to the conversion of land use towards changes in the characteristics of the surrounding rural areas. Changes in land use will affect the socio-economic conditions of the community and contribute to the intensity of urban flooding events (Atharinafi and Wijaya, 2021; Huang and Liu, 2022). Furthermore, the weak control over the use of space and the ease of permits issued by the government have an impact on the complexity of land use and urban transportation systems (Kobayashi et al., 2020; Siriwardane-de Zoysa et al., 2021). This means that development activities that continue to increase have a positive correlation with the decline in the environmental quality of the Mamminasata Metropolitan new city area. The dominant development orientation on economic activity has a positive correlation with the decline in environmental quality and public health (Zahra et al., 2022; You, 2022). The strategic steps needed in relation to controlling the use of space in the new city area are, among others: (1) realizing spatial utilization guidelines through optimizing land use management; (2) organize settlements in a comprehensive and integrated manner along with the proportional preparation of green open spaces; and (3) optimizing community participation in the process of controlling environmental pollution. Third, it will require cooperation between the government, the private sector, and the community. Cooperation between the government and public service organizations is oriented towards increasing organizational efficiency towards increasing economic productivity, social welfare, and environmental sustainability (Rösler et al., 2021; Jean-Quartier et al., 2022).

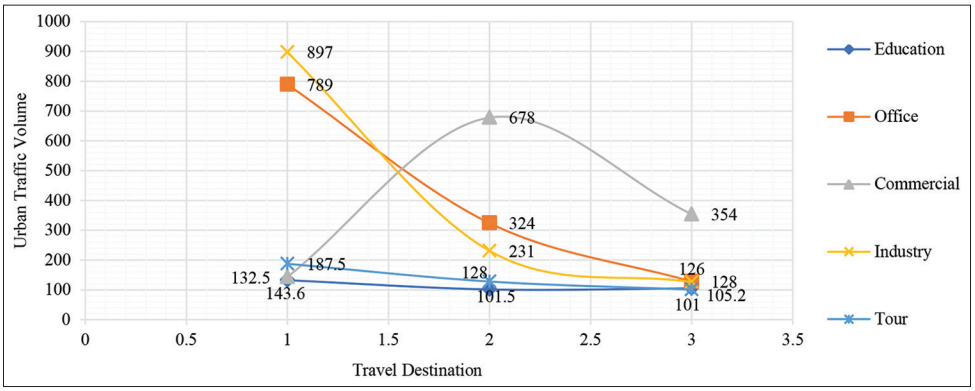
Figure 6: Travel patterns of residents of the Mamminasata Metropolitan new city area



Information	
A: New city area	D: Location of industrial activities
B: Location of educational activities	E: Location of tourist activities
C: Location of office activities	F: Location of commercial activities

In order to support the restoration of the environmental quality of the new city area, in addition to the need for effectiveness in space utilization, support for the use of renewable energy is also needed. Three categories of renewable energy are needed to support the development of the new Metropolitan Mamminasata city area, namely: First, solar energy using a panel system that is arranged in a residential environment in such a way that it is effective in absorbing sunlight. Solar cells function to absorb sunlight and convert sunlight into electrical energy. Furthermore, the utilization of the solar panel system is used for street lighting, home lighting, and increasing the productivity of the community's economic business (Orejon-Sanchez et al., 2021; Hernita et al., 2021; Pandey et al., 2022). Second, wind energy uses a propeller that is connected to a special tool that functions to convert wind energy into mechanical strength as an electrical conductor. The third is water energy, its use is through the construction of waiting reservoirs that function to accommodate water for distribution to housing units using a pumping system and its function is used for urban flood

Figure 7: Mamminasata Metropolitan urban traffic volume



Source: Primary data

control. Meeting the need for drinking water will help in supporting the increase in community economic productivity and meeting the needs of urban industry (Wang, 2021; Fisher and Smith, 2022). Furthermore, the effect of controlling space utilization, renewable energy utilization, and transportation management on improving the environmental quality of the Mamminasata Metropolitan new city area, is presented in Table 2 below.

The results of Table 2 which can be explained include: (1) Control of spatial use affects the improvement of the environmental quality of the new city area; (2) The use of renewable energy has an effect on improving the environmental quality of the new city area; and (3) transportation management has an effect on improving the environmental quality of the new city area. Thus, it can be concluded that the effect of space utilization, renewable energy utilization, and transportation management simultaneously explains 94.84% of the sustainability of the Mamminasata new city area. Furthermore, the use of renewable energy contributes to economic activities and reduces carbon emissions, especially those produced by human activities (Surya et al., 2021; Khalil et al., 2022).

3.4. Sustainability of Mamminasata Metropolitan New City Area Development

The sustainable development of the Mamminasata Metropolitan new city area is contextualized in three main things, namely: First, environmental sustainability which is oriented to land use regulation and optimization of natural resource potential utilization based on renewable energy utilization coupled with spatial use control. This means that planning coordination is needed to support the preparation of energy infrastructure that is integrated with optimization of land use management (van de Ven et al., 2021; Schneider et al., 2022). Second, economic sustainability is synergized with the use of natural resources and the environment to ensure the continuity of ecological functions and the fulfillment of intergenerational needs. The sustainability of the economic system will create new opportunities for the development of competitiveness, innovation, and employment opportunities for the community (Awais et al., 2019; Pirlone et al., 2022). Third, social sustainability is oriented towards social justice and social cohesion through support for the distribution of land resources and production factors, increasing the role of women and fulfilling job opportunities towards improving community welfare. A cohesive society is characterized by the availability of basic facilities, equality, economic inclusion, democracy, and social solidarity towards the realization of the values of openness, trust, empowerment, and community solidarity (Curtis et al., 2020; Jayakody et al., 2022). Thus, the sustainability of the new urban area is implemented through the integration of the natural system, development system, and urban social system of the Mamminasata Metropolitan. Urban sustainability will require the implementation of policies, namely political, economic, environmental, and cultural systems towards interaction and integration between biotic, physical, social, and built environment components (Han et al., 2021; Mokhtari et al., 2022; Xie et al., 2022). Furthermore, the model for the use of renewable energy and the sustainable development of new urban areas is presented in Figure 8.

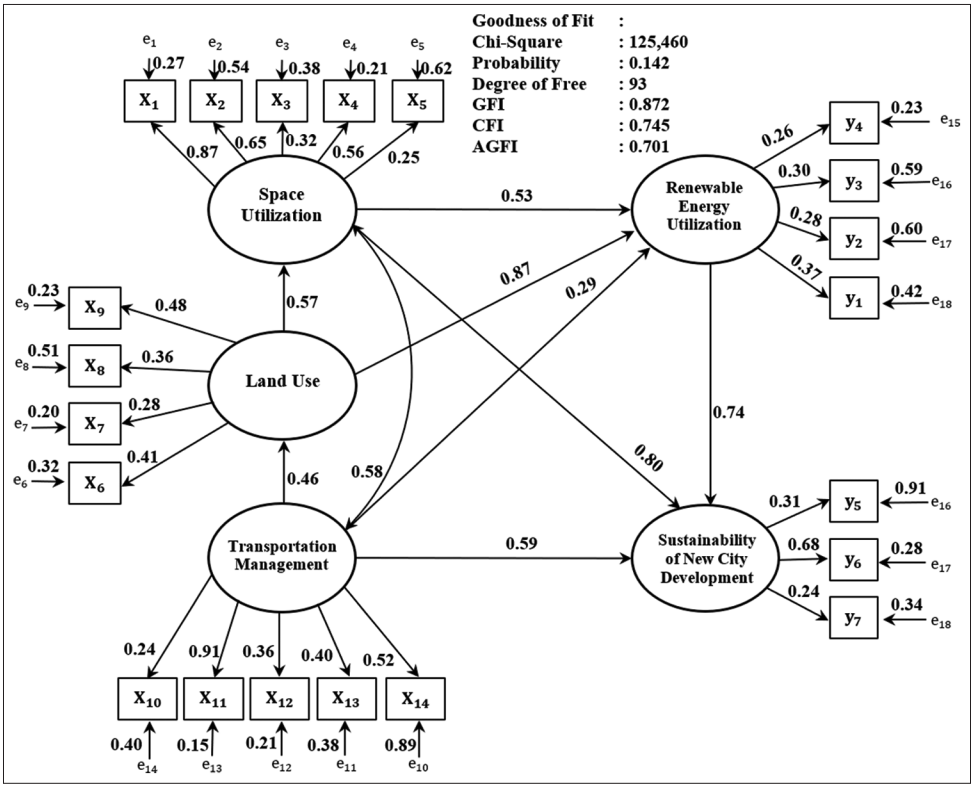
Figure 8 shows a model for the estimation of the sustainability of the development of the new Mamminasata city area. The possible interpretations of the developed model include: First, the variables of spatial use, land use, transportation management, and the use of renewable energy simultaneously affect the sustainability of the development of the new city area of Metropolitan Mamminasata. The results of the chi-square test show a value of 125.460 with a probability $P = 0.142 > 0.05$, $df = 93$, $GFI = 0.872$, $CFI = 0.745$, dan $AGFI = 0.701$. These results confirm that the built model is categorized as a fit model. Second, the total effect of space utilization on the endogenous variable of the use of new city space on the endogenous variable of renewable energy use is 0.2809 or 28.09%, land use on the endogenous variable of renewable energy utilization in the new city area is 0.7569 or 75.69%, transportation management on the endogenous variable of utilization renewable energy in the new city area by 0.0841 or 8.41%. Third, the use of space for the sustainability of new city area development is 0.64 or 64%, transportation management is 0.3481 or 34.81% for the sustainability of new urban area development and infrastructure development is 0.5776 or 57.76% of the endogenous variables for the sustainability of new urban area development. Fourth, the total effect of the use of renewable energy on the sustainability of the development of the Mamminasata new city area is 0.5476 or 54.76%. Thus, it can be concluded that the effectiveness of spatial use, optimization of land use, transportation management, and the use of renewable energy simultaneously affect the sustainability of the development of the Mamminasata new city area. Management of activities, land use and optimal spatial distribution will reduce

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

Correlation	Coefficient	Error	t-count	t-table
	β	S_{bi}		
Controlling the use of space to improve the environmental quality of the new city area ($ry\times_1$)	0.192	0.065	2.875	1.94
Utilization of renewable energy to improve the environmental quality of the new city area ($ry\times_2$)	0.148	0.062	2.856	1.94
Transportation management to improve the environmental quality of the new city area ($ry\times_3$)	0.408	0.098	4.192	1.94

Source variant	Sum of squares (JK)	Free Degrees (db)	Average of the sum of the squares (RJK)	F-count	F-table α = 0.05
Regression	21.730	3	6.747	86.941	5.67
Residue	0.482	6	0.074		
Total	21.730	9	-	-	-
R	R^2	db1	db2	F-count	F-table
0.979	0.9484	3	6	86.941	5.67

Figure 8: The estimation model for the sustainability of the Mamminasata Mentropolitan new city area development



Source: Analysis results

carbon emissions and land degradation towards sustainable development (Wang et al., 2021; Lovering et al., 2022; Surya et al., 2022).

The strategic steps needed to optimize the development of the Mamminasata Metropolitan new city area, among others: (1) Involvement of community participation in improving environmental quality, which is carried out through socialization for the purpose of changing behavior and building public awareness; (2) Optimizing the use of renewable energy to support the fulfillment of energy needs both for households and other socio-economic activities; (3) The shift in the use of fossil energy which has been used to meet the needs of transportation means towards the use of renewable energy based on electrical energy and biodiesel; and (4) Maximizing support for providing green open space to anticipate potential flood disasters towards natural disaster mitigation management. These four things will require the support of government, private and community policies and be implemented in an integrated and cross-sectoral nature (Surya et al., 2021; Ananthapavan et al., 2022).

4. CONCLUSION

The allocation of space utilization for the new Mamminasata Metropolitan area which is dominantly developed for the needs of large-scale housing and settlement development as well as the fulfillment of infrastructure needs has a direct effect on changes in forest cover, land use conversion, and environmental degradation. Development activities that tend to increase in addition to causing high pollution loads also have an impact on the destruction of mangrove forest habitat due to coastal reclamation. The pattern of population mobility from the direction of the new city area to the centers of socio-economic activity has an impact on the complexity of the transportation movement system, traffic congestion, and air pollution originating from motor vehicle exhaust gases. The effectiveness of spatial use towards restoring the environmental quality of the Mamminasata new city area will require optimal management of land resources, tightening the use of water catchment areas, river borders, and beaches synergized with the use of renewable energy to support the fulfillment of household energy needs and socio-economic activities. The utilization of renewable energy is integrated with the provision of green open space towards reducing emission levels and controlling environmental pollution.

Utilization of space in the new city area will require the implementation of policies and strategic steps, namely: (1) Realizing spatial use guidelines through optimizing land use management; (2) Organizing settlements in a comprehensive and integrated manner along with the proportional preparation of green open spaces; and (3) Optimizing community participation in the process of controlling environmental pollution. Third, it will require cooperation between the government, the private sector, and the community. Thus, controlling the use of space is directed to support the improvement of environmental quality that is integrated with the use of renewable energy and management of the transportation system towards the sustainable development of the new city area of Metropolitan Mamminasata.

Optimizing the management of the new urban area of the Mamminasata Metropolitan Area is focused on three strategic

points, namely: (1) Realizing spatial use tips through optimizing land use management; (2) Organizing settlements in a comprehensive and integrated manner along with the proportional preparation of green open spaces; and (3) Optimizing community participation in the process of controlling environmental pollution. Third, it will require cooperation between the government, the private sector, and the community. Thus, optimization is needed in the implementation of the development of new urban areas through strategic steps, namely: (1) Involvement of community participation in improving environmental quality, which is carried out through socialization for the purpose of changing behavior and building public awareness; (2) Optimizing the use of renewable energy to support the fulfillment of energy needs both for households and other socio-economic activities; (3) The shift from the use of fossil energy to the use of renewable energy based on electricity and biodiesel; and (4) Maximizing support for providing green open space to anticipate potential flood disasters based on natural disaster mitigation.

5. FUNDING

We would like to thank the stakeholders who have provided ideas and ideas for the implementation of this study. Thank you to the Ministry of Education, Culture, Research and Technology of the Republic of Indonesia and Bosowa Foundation for their support and financial assistance in the implementation of this study.

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