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The Complexity of Space Utilization and Environmental Pollution Control in the Main Corridor of Makassar City, South Sulawesi, Indonesia

Batara Surya [1,*], Hamsina Hamsina [2], Ridwan Ridwan [2], Baharuddin Baharuddin [3], Firman Menne [4], Andi Tenri Fitriyah [5] and Emil Salim Rasyidi [6]

1 Department of Urban and Regional Planning, Faculty of Engineering, University Bosowa, Makassar City 90231, Indonesia
2 Department of Chemical Engineering, Faculty of Engineering, University Bosowa, Makassar City 90231, Indonesia; hamsina.ruslan@ymail.com (H.H.); ridwan@universitasbosowa.ac.id (R.R.)
3 Department of Agricultural Socio–Economic, Faculty of Agriculture, University Bosowa, Makassar City 90231, Indonesia; baharuddin@universitasbosowa.ac.id
4 Department of Accounting, Faculty of Economic and Business, University Bosowa, Makassar City 90231, Indonesia; firman@universitasbosowa.ac.id
5 Department of Agricultural Agribusiness, Faculty of Agriculture, University Bosowa, Makassar City 90231, Indonesia; tenri.fitriyah@universitasbosowa.ac.id
6 Department of Urban Planning, Faculty of Engineering, University Bosowa, Makassar City 90231, Indonesia; emil.salim@universitasbosowa.ac.id
* Correspondence: batara.surya@universitasbosowa.ac.id

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Abstract: Population mobility, increasing demand for transportation, and the complexity of land use have an impact on environmental quality degradation and air quality pollution. This study aims to analyze (1) the effect of population mobility, increased traffic volume, and land use change on air quality pollution, (2) direct and indirect effects of urban activities, transportation systems, and movement patterns on environmental quality degradation and air pollution index, and (3) air pollution strategy and sustainable urban environmental management. The research method used is a sequential explanation design. Data were obtained through observation, surveys, in-depth interviews, and documentation. The results of the study illustrate that the business center and Daya terminal with a value of 0.18 µgram/m^3 is polluted, the power plant and Sermani industrial area with a value of 0.16 µgram/m^3 is polluted, the Makassar industrial area with a value of 0.23 is heavily polluted, and the Hasanuddin International Airport area with a value of 0.04 µgram/m^3 is not polluted. Population mobility, traffic volume, and land use changes have a significant effect on environmental quality degradation, with a determination coefficient of 94.1%. The direct effect of decreasing environmental quality on the air pollution index is 66.09%. This study recommends transportation management on the main road corridor of Makassar City, which is environmentally friendly with regard to sustainable environmental management.

Keywords: space utilization complexity; population mobility; transportation demand; air pollution; environmental management

1. Introduction

Excess urbanization followed by an increase in socio-economic activity, in the case of large and metropolitan cities in Asia, is characterized by a population increase of 24% annually. Urbanization is directly related to economic growth and the expansion of cities towards urban suburbs [1]. The large cities in Asia have a tendency to rely on an economic growth magnet that is dominant and centrally developed in urban areas. Urbanization is directly related to economic growth and expansion of the core city towards the suburban area [2]. Furthermore, the urbanization process, which is quite high and is not matched by controlling the use of space and increasing the welfare of society economically, has a positive contribution to the decline in environmental quality [3]. Urbanization in Central Asia has made a positive contribution to prosperity and its impact on socio-economic inequality. Expansion of urban areas due to an increase in population and support for infrastructure development and transportation systems, apart from having an impact on environmental quality degradation, also contributes to changes in land use [4,5]. Thus, it is predicted that 1.1 billion people will live in urban areas over the next 20 years, and 55% of the population in Asia will live in cities [6].

Tokyo-Nagoya-Osaka-Kyoto-Kobe has a population of over 60 million. Furthermore, the City of Bangkok, Thailand, has expanded its city area to 200 km from the city center location. Furthermore, the massive urbanization in China has triggered the expansion of residential areas and encouraged increased mobility with motorized vehicles. Increased public welfare has a positive correlation with the use of urban transportation modes. The increase in population and the concentration of the population, which is quite high, has an impact on increasing travel mobility and transportation logistics [6,7]. The number of registered vehicles in Beijing City has increased from around one million in the early 1990s to nearly 61 million in 2010. Furthermore, the integration of the transportation system contributes to the use of motorized vehicles and the impact on environmental pollution and city air quality. The high use of motorized vehicles is the main source of decline in urban air quality [8,9]. Furthermore, in order to face the challenges of climate change and changes in urban typology, its relationship with increasing population density, the orientation of mixed land use, connectivity of urban systems, and fulfillment of green open spaces will help reduce CO_2 emissions. This means that an integrated climate change mitigation strategy can be implemented using spatial planning, transportation development, and urban planning in cities [10,11].

The development orientation in Indonesia is dominant in the industrial and service sectors, and its space allocation is predominantly located in large and metropolitan cities. Several factors that support the increase in industrial and service activities are the result of support for the availability of various supporting facilities, ease of investment, and cheap labor. The technological revolution has made a positive contribution to the labor market and has adapted to the rapidly changing global situation and its impact on improving urban transportation services [12]. For the period 2018–2019, there were 14 cities in Indonesia that showed good air quality, 22 cities with moderate air quality conditions, and 8 cities categorized as unhealthy air quality. Furthermore, the annual average PM 2.5 for large cities such as Jakarta is 34.57 micrograms/cubic meter. This figure has exceeded the national quality standard, namely 15 micrograms/cubic meter. If you refer to the WHO standard of 10 micrograms/cubic meter, this figure indicates that the condition has more than tripled.

The growth of vehicles in Indonesia is 12% per year, with the largest composition being motorbikes. This condition not only causes traffic jam problems, but also other problems such as traffic accidents, air pollution, and noise. Furthermore, 70% of urban air pollution is generated by motor vehicles. Thus, the use of fossil fuels in the urban transportation sector has a significant effect on global warming. The high intensity of motorized vehicles using fossil fuels in many countries causes a decrease in environmental quality, health problems, and their impact on the social and economic conditions of society [13].

The development dynamics of Makassar City show the same thing. The indication is assessed based on the percentage of air pollution levels that are categorized as unhealthy and threatening public health, with an air pollution index reaching 87.83–90%. The biggest contributor to pollution is smoke containing carbon monoxide (CO_2) from motor vehicles and industrial activities [14]. Thus, the increase in the growth of motorized vehicles, household activities, trade, and industry, is very fast contributing positively to the increase in air pollution in Makassar City. There are four urban development factors of NOX emissions per capita: The intensity of NOX emissions from gasoline consumption, the proportion of gasoline-powered vehicles, vehicle use in the urban population, and the degree of urbanization [15,16]. Land use change coupled with population mobility in the corridor of the Urip Sumoharjo-Perintis Kemerdekaan Makassar City contributes positively to air pollution and a decrease in the quality of the surrounding environment.

The complexity of space utilization on the Urip Sumoharjo-Perintis Kemerdekaan road corridor is indicated by the presence of activities including: (1) 33.18 hectares of housing and settlements; (2) offices cover 42.59 hectares; (3) shopping centers, services, hotels, and traditional markets covering an area of 100.2 hectares; (4) education centers consist of colleges and high schools covering an area of 20.59 hectares; (5) health service centers consisting of hospitals and auxiliary health centers covering an area of 4.99 hectares; (6) industrial activity center covering an area of 7.72 hectares; and (7) Hasanuddin Mandai International Airport area of 195.79 hectares. The complexity of space utilization on the Urip Sumoharjo-Perintis Kemerdekaan road corridor has a direct impact on environmental degradation. This condition is characterized by an increase in the volume of waste generation, household waste, and dust particles. The implementation of several urban functions has caused side effects in the form of emission of substances that contribute to air pollution and municipal solid waste disposal, and an increase in the volume of waste generation creates serious environmental problems and air pollution [17,18]. Thus, the urban ecosystem is a unified system that is influenced by developing activities [19].

Increase in socio-economic activities on the Urip Sumoharjo-Perintis Kemerdekaan road corridor is marked by a fairly, high population mobility. The volume of vehicles tends to increase, due to the role of the corridor in addition to connecting several urban areas of Makassar City, it also functions as a primary arterial road that connects transportation movements from the direction of Maros City to the center of Makassar City. Furthermore, in the rush hour situation, the flow of vehicles crossing the Urip Sumoharjo-Perintis road corridor was 903,108 pcu/hour/day, consisting of 872,480 units of private vehicles, 13,681 units of passenger transport, 41,042 goods transportation, two-wheeled vehicles consisting of bicycles, motorbikes, motorized pedicabs, and bentor as many as 719,069 units. Apart from having an impact on traffic congestion and traffic accidents, the space utilization complexity and high traffic volume also have an impact on air quality pollution produced by vehicle fumes and particles, incineration of domestic waste, and waste from city activities. Traffic congestion increases vehicle emissions and degrades ambient air quality, and recent studies have shown excess morbidity and mortality for drivers, commuters, and individuals living near major roadways [20].

Physical spatial changes have an impact on the development activities of residential areas, shopping centers, trade, industry and transportation which have an impact on increasing mobility, daily traffic volume, decreasing environmental quality, and air quality pollution, especially in the main city road corridors [21]. Air pollution is a combination of particulate matter (PM), and gases released into the atmosphere due to industrial activities, motorized vehicles, and power plants, as well as waste incineration [22]. Thus, pollutants can be classified into two categories, namely primary or secondary: Primary pollutants are released directly into the atmosphere, whereas secondary pollutants are generated from chemical reactions between primary pollutants [23]. Furthermore, air pollution not only has an impact on climate change but also has an impact on public health [24]. Thus, the complexity of space utilization in line with the increased mobility of the population coupled with a fairly high traffic volume on the main city roads contributes positively to the decline in environmental quality and air pollution.

Air quality pollution and environmental degradation are serious problems to be addressed in the case of Makassar City. Air pollution comes mainly from motor vehicle exhaust gases, industrial activities, and household waste. Thus, the focus of this study is aimed at determining (1) the effect of population mobility, increased traffic volume, and land use change on air quality pollution, (2) the direct and indirect effects of urban activity systems, transportation systems, and the origin-destination patterns of movement on environmental quality degradation and the air pollution index, and (3) strategies to control air pollution and sustainability in urban environmental management.

2. Conceptual Framework

Population mobility in Makassar City is marked by an increase in the flow of transportation movements from direction the settlement to the workplace, educational facilities, shopping centers, and social facilities using private vehicles, public transportation, and motorbikes. Transportation is the movement of people or goods from one place to another or from their place of origin to their destination using media that is moved by humans, animals, and machines [25]. The role of transportation services is aimed at accelerating and facilitating the movement of people or goods from the area of origin to the destination. The function of transportation is divided into two important roles: (1) transportation as a supporting sector for the development of other sectors' activities and (2) the function of transportation as a driver, in the sense of providing effective transportation services to link one activity to another in the direction of spatial, economic, and social interactions [26]. The main challenge for urban growth is transportation, including pollution, congestion, accidents, decreased public transportation, environmental degradation, climate change, energy depletion, visual disturbances, and the lack of accessibility for the urban poor [27].

Population growth followed by increased economic activity has an impact on the mobility of goods and people transport from the origin to the destination. In the process of population mobility, the factors of safety, comfort, and on time to the destination are important things to consider [28]. Furthermore, industrial activities and motorized vehicles cause air quality in large cities to become increasingly polluted. Air pollution is the addition of a physical or chemical material or substrate into the normal air environment, which reaches a certain amount, so that it can be detected by humans or can be calculated and measured, and has an effect on humans, animals, vegetation, and materials due to human activity [29]. Furthermore, air pollution is defined as a state of the atmosphere, where one or more polluting substances whose amount and concentration can endanger the health of living things, damage property, and reduce air comfort [30].

Air pollution can be divided into two categories: (i) Free air pollution and (ii) indoor air pollution. Materials or substances that can pollute the air can be in the form of gases and particles based on physical characteristics. Pollutants can be in the form of particles (dust, aerosol, and lead), gases (CO, NOX, SOX, and H2S), and energy (temperature and noise) and, according to the event or formation, can be divided into two categories: (i) Primary pollutants, i.e., those emitted directly by the source, and (ii) secondary pollutants, i.e., those formed due to reactions in the air between various substances [31,32].

Referring to the conceptualization of the theory that has been explained, in this study, air pollution is measured based on the air quality index set by the government of the Republic of Indonesia. This index is commonly used by government agencies to show how bad the air quality in an area or city is. The indeks standar air pollutant (ISAP) parameters are particulates with a diameter of less than 10 μm (PM10), carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), and ozone (O_3). ISAP measurement parameters are in Table 1, the category of air pollution index in Table 2, the effect of the ISAP for each pollutant parameter is shown in Table 3, and the research conceptual framework is shown in Figure 1.

Table 1. Measurement period for mean indeks standar air pollutant parameters.

Number	Parameter	Time
1	Particulate, PM10	24
2	Sulfur dioxide, SO_2	24
3	Carbon monoxide, CO	8
4	Ozone, O_3	1
5	Nitrogen dioxide, NO_2	1

Source: Reference [33].

Table 2. Air pollution standard index.

Air Pollution Standard Index	Air Pollution Level	Health Impact
0–50	Well	has no impact on human or animal health
51–100	Moderate	it does not affect human or animal health but affects sensitive plants.
101–199	Not healthy	is detrimental to humans or groups of animals that are sensitive or can cause damage to plants or aesthetic value.
200–299	Very Unhealthy	air quality which can be detrimental to health in some exposed segments of the population.
300–500	Dangerous	hazardous air quality which can generally have serious health detrimental to the population (eye irritation, cough, phlegm, and sore throat).

Source: Reference [33]. Table 2 shows the standard index of air pollution with the following explanations: (1) The green color indicates that air quality is categorized as good; (2) The orange color indicates that the air quality is categorized as medium; (3) The yellow color indicates that air quality is categorized as unhealthy; (4) The red color indicates very unhealthy air quality; and (5) Dark red-black color illustrates dangerous air quality.

Table 3. Effect of indeks standar air pollutant for each pollutant parameter.

Category	Range	CO	NO_2	O_3	SO_2	Particulate
Well	0–50	There is no effect	Slight odor	Wounds in several plant species due to combination with SO_2 for 4 h	Wounds in several plant species due to the combination of O_3 for 4 h	There is no effect
Moderate	51–100	Blood chemistry changes but is not detectable	Odor	Wounds in some plant species	Wounds in some plant species	There is a decrease in visibility
Not healthy	101–199	Increase in cardiovascular symptoms in smokers with heart disease	Odor and loss of color, increased reactivity of the throat vessels in asthmatics	Decrease in the ability of athletes who train hard	Odor, increased crop damage	Visibility drops and there is dust fouling everywhere
Very Unhealthy	200–299	Increased cardiovascular symptoms in nonsmokers with heart disease and some noticeable weakness	Disorders of asthma and bronchitis	Moderate exercise exerts respiratory effects in patients with chronic lung disease	Increased symptoms of asthma and bronchitis	Increased sensitivity to asthma and bronchitis
Dangerous	≥300	Dangerous levels for all exposed populations.				

Source: Reference [33].

Tables 1–3 are the basis and parameters used as a reference for measuring the level of air quality pollution in the Urip Sumoharjo-Perintis Kemerdekaan road corridor based on the complexity of space utilization and mobility of population movements in relation to various sources of pollution to the air quality it causes. The air pollutant standard index is a public air quality report to explain how clean or polluted the air quality is and how it affects health after breathing air for several hours or days. The determination of the air pollutant standard index considers the level of air quality on the health of humans, animals, plants, buildings, and aesthetic values. The standard air pollutant index is measured based on five main categories, namely (i) carbon monoxide (CO), (ii) sulfur dioxide (SO_2), (iii) nitrogen dioxide (NO_2), (iv) surface ozone (O_3), and dust particles. (PM10). Air pollutant standard index refers to the regulations set by the government. Furthermore, standard index limit for air pollutants in units (see Table 3) is presented in Table 4.

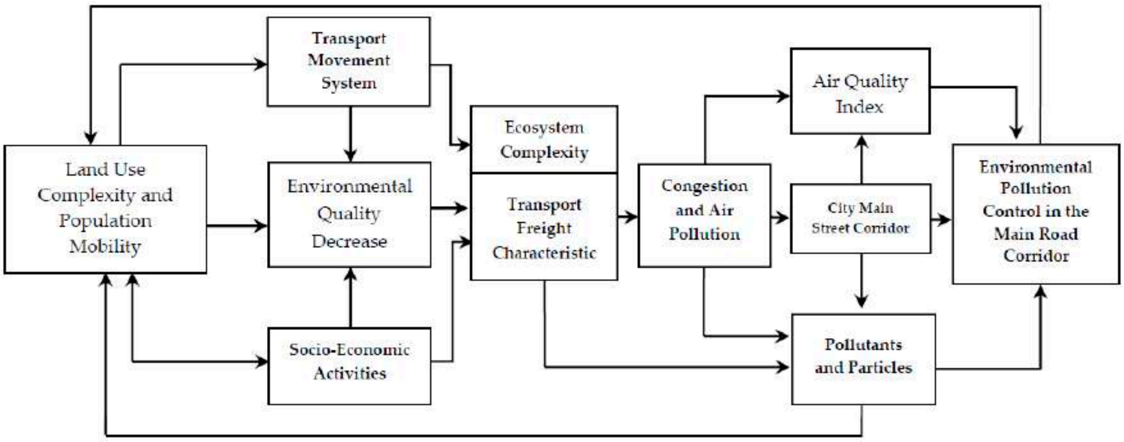

Figure 1. Conceptual framework land use change and environmental pollution control in the main road corridor. Source: Author's elaboration.

Table 4. Air pollutant standard index limits.

Air Pollutant Standard Index	24 h PM10 ug/m^3	24 h SO_2 ug/m^3	B hour CO ug/m^3	1 h O_3 mg/m^3	1 h NO_2 ug/m^3
10	50	80	5	120	(2)
100	150	365	10	235	(2)
200	350	800	17	400	1130
300	420	1600	34	800	2260
400	500	2100	46	1000	3000
500	600	2620	57.5	1200	3750

Source: Reference [33].

2.1. Review Theory

The socio-economic development activities that tend to increase in the dynamics of Makassar City development are mostly developed in the main city road corridors. The existence of these activities has a positive contribution to increasing population mobility, decreasing environmental quality and air pollution. Urban air pollution is largely and increasingly the result of the combustion of fossil fuels for transport, power generation, and other human activities. Combustion processes produce a complex mixture of pollutants that comprises both primary emissions, such as diesel soot particles and lead, and the products of atmospheric transformation, such as ozone and sulfate particles formed from the burning of sulfur-containing fuel [34]. Air pollution has a positive contribution to increase air temperature and public health. Recent years, public health problems have a tendency, to increase due to climate change and industrialization [35]. Thus, the increase in industrial activities, commercial activities, office activities, educational activities, and other economic activities followed by the modernization of the development of Makassar City will have a positive contribution to population mobility and contribute positively to the decline in environmental quality and increase in air pollution. Furthermore, increase in the level of GHG changes the energy balance between the atmosphere and Earth's surface, which in turn can cause temperature changes that change the chemical composition of the atmosphere. Climate change may affect exposures to air pollutants by affecting weather, anthropogenic emissions, and biogenic emissions and by changing the distribution and types of airborne allergens. Local temperature, precipitation, clouds, atmospheric water vapor, wind speed, and wind direction influence atmospheric chemical processes, and interactions occur between local and global-scale environments [36]. Live emissions of air pollutants (carbon black), or those formed from emissions such as sulfate and ozone, can also affect this energy balance. Thus, climate change and air pollution management have consequences for one another [37].

Air pollution is a condition in which the presence of one or more chemical, physical, and biological substances in the atmosphere in dangerous quantities. Air pollution is defined as a phenomenon harmful to the ecological system and the normal conditions of human existence and development when some substances in the atmosphere exceed a certain concentration [38]. Increased levels of pollution in the air have been identified as having an impact on human, animal, and plant health, aesthetics, comfort, and property. This means that urban areas are characterized by pollution originating from solid particles and motor vehicle exhaust fumes [39]. Furthermore, air pollution can come from various kinds, namely motor vehicle fumes, factory fumes, industrial waste, household waste, and others. The increase in energy consumption in urban areas causes an increase in air pollution, which endangers human health, damages crops, and contributes positively to climate change [40]. About more than 70% of air pollution in Indonesia including Makassar City, motor vehicle emissions. This means that motorized vehicles emit hazardous substances that can cause negative impacts, both on human health and on environmental conditions. These hazardous substances include lead/lead (Pb), suspended particulate matter (SPM), nitrogen oxides (NOx), hydrocarbons (HC), carbon monoxide (CO), and photochemical oxides (Ox). Motor vehicles contribute nearly 100% of lead, 13–44% of suspended particulate matter (SPM), 71–89% of hydrocarbons, 34–73% of NOx, and almost all of carbon monoxide (CO) to the air. Urban development followed by an increase in population results in high energy consumption and unhealthy levels of air emissions [41,42].

That occurs continuously in big and metropolitan cities, including in the case of Makassar City, has an impact on several things, including: (1) Health impacts, due to the increase in dust particles in the air. Dust pollution causes lung disease (bronchitis) and other respiratory diseases. Meanwhile, the impact of pollution by chemicals such as carbon monoxide can cause health problems in hemoglobin. Hemoglobin is an oxygen-carrying metaloprotein that contains iron in red blood cells; (2) the results of a World Bank study found that the economic impact of air pollution in Indonesia is Rp. 1.8 trillion; (3) the social impact due to air pollution means that people cannot enjoy healthy air, meaning that every day they have to see and breathe smoke produced by motorized vehicles and industrial activities. As a result, social activities are hampered. (4) The greenhouse effect is caused by the presence of CO2, CFCs, methane, ozone, and N2O in the troposphere. All of this gas absorbs solar thermal radiation reflected by the earth's surface. As a result, heat is trapped in the troposphere, causing the phenomenon of global warming; and (5) ozone layer damage, the ozone layer in the stratosphere (20–35 km altitude) is the earth's natural protector. This layer functions to filter ultraviolet B radiation from the sun and cause skin cancer and diseases in plants. Damage to the ozone layer has a negative impact on human health, decreased human immunity, and skin cancer [43].

Furthermore, referring to housing as a "risk factor" would mask the important role that it plays in providing a setting for daily household and community activities. At the same time, it is important to acknowledge the important and complex roles that housing and neighborhood design play in public health and to promote systematic inclusion of health in the design of housing, housing technology, and the urban and regional planning processes. However, diving deeper into the housing debate reveals that there are a host of moral values already present throughout this debate that are often not explicitly articulated and explicated, such as inclusiveness, sustainability, autonomy, and security [44]. Thus, the high complexity of space utilization and increased population mobility by using motorized vehicles and the presence of dense settlements on the Urip Sumoharjo-Perintis Kemerdekaan road corridor have contributed positively to the degradation of environmental quality and air quality pollution.

Study results that support this research include: First, research was conducted by Zou, B [45], by analyzing the effect of land use and changes in cover on air quality. The results of this study confirm that serious consideration is needed regarding the configuration of land use to improve urban air quality and the effectiveness of government policies in terms of urban air quality control. Second, a study was conducted by Jiang, M [46], examining the relationship between gross regional product per capita and industrial emissions from sulfur dioxide emissions using a simultaneous equation model for 286 cities in China and 228 cities and counties in South Korea of the period 2006–2016. The results of this study show the difference in the relationship between air pollution and economic growth in the two countries. The study found that the level of pollutant emissions in China's metropolitan areas is much higher than in non-metropolitan areas, in contrast to Korea.

Third, a study was conducted by Author Hankey, S and Marshall, J.D [47], with the title: Urban Form, Air Pollution, and Health. The focus of this study was urban forms that can affect air pollution and public health. This study examines two main things, namely: (1) The relationship between urban forms, air pollution, and health; and (2) aspects of the urban environment (i.e., green spaces, noise, physical activity) that can alter these relationships. The study found that urban forms can support efforts to design clean and healthy cities. This study found that a special strategy is needed to explain the causal pathways that link the factors of population movement, increased urban activity, and its effects on aspects of human health. Fourth, a study was conducted by Molina, L.T [48], by analyzing the effect of population growth and increased energy consumption in urban areas. This study compares the policies implemented in the Metropolitan area of Mexico City and Singapore and offers air pollution management to protect public health and the environment. This study found that differences in governance, economy, and culture in the two cities affect the decision-making process to reduce the concentration of hazardous pollutants, so it is necessary to implement an integrated and comprehensive air quality management program.

The results of the four studies show that the growth of large and metropolitan cities is characterized by changes in land cover, increased economic productivity, changes in land cover, increased population, and energy consumption, which has an impact on decreasing quality and increasing air pollution which endangers public health. The four results of the study are at a meeting point with the affirmation that the complexity of the development of large and metropolitan cities has a positive contribution to ecosystem damage and air pollution. Thus, this study focuses more on the analysis of: (1) The effect of population mobility, increased traffic volume, and land use changes on air quality pollution; (2) direct and indirect effects of urban activity systems, transportation systems, and origin-destination movement patterns on environmental quality degradation and air pollution index; and (3) strategies for handling air pollution and sustainable urban environmental management.

2.2. Land Use Complexity and Population Mobility

Land use change and weak control over space use in the Urip-Sumoharjo-Perintis Kemerdekaan road corridor are positively correlated with a decrease in environmental quality and air pollution. High population concentrations are positively correlated with traffic problems and environmental degradation [49], the dominant development towards an economic function has an impact on spatial and ecosystem pressures towards land use change [50]. Furthermore, the mobility of the urban population is characterized by an increase in traffic volume and the variety of modes of transportation used by the community. The characteristics and types of transportation modes that increased economic activity and industrialization have a positive correlation with decreasing air quality due to the emissions produced [51,52]. The complexity of land use is measured based on the ratio of the built-up area that uses land to the undeveloped area in a certain area. Indicators of the complexity of urban land use are indicated by the existence of functions of socio-economic activities, among others: Education, offices, shops, shopping centers, housing and settlements, industry, services, and other socio-economic activities. Since activities have a different location, their separation is a generator of movements of passengers and freight, which are supported by transportation. Therefore, transportation and land use are interrelated because of the locational and interactional nature of urban activities [53].

2.3. Sustainability of Environmental Management and City Transportation Systems

Environmentally sound development is a conscious and planned effort to use and manage resources wisely in a planned and sustainable development to improve the quality of human life. The implementation of environmentally sound development and the wise, controlled use of natural resources are the main objectives of environmental management. Thus, urban environmental management policies and urban transportation systems are important aspects of sustainable development. Good city governance is when the implementation of development policies involves active community participation in environmental management [54].

The urban transportation system includes road length, road network patterns, road conditions, public transportation vehicles, goods transportation, and private vehicles. Urban transportation has a relationship to the city's rapidly developing economic system. This means that it requires sustainable transportation management [55]. Furthermore, there are five main elements that play an important role in the urban transportation system: (i) Humans, who need transportation; (ii) goods, i.e., things that are needed or consumed by humans; (iii) vehicles, which function as a means of transferring or transferring people and goods from one place to another; (iv) roads, as transportation infrastructure or media; and (v) organizations or institutions that act as transportation managers. The transportation system consists of a network sub-system (means of transportation), a movement subsystem (vehicles and transportation media), an activity sub-system (people and goods), and an institutional sub-system (organization). The institutional system functions to optimize system functions through policy, planning, transportation, and financial system plan realization—funding. The transport system is a complex system in itself and includes several subsystems: Urban passenger public transport, the route network, the street and road network, and the management of traffic lights. These systems include elements such as intelligent transport systems, the traffic flow of light and heavy vehicles, and vehicles of individual owners, organizations, and taxi companies [56].

3. Material and Method

3.1. Research Design

The qualitative approach in this study is used to investigate, describe, and explain the phenomena of changes in space use, population mobility, and traffic volume in the Sumoharjo-Perintis Kemerdekaan Urip road corridor. Furthermore, theory is used as a guide and reference in determining the focus of research. The main instrument in qualitative research is the researcher himself to trace data in the field. Thus, qualitative research is the initial resistance used by research to collect data. The data referred to, among others; tracking data on land use, traffic volume, and activity systems that have the potential to cause environmental pollution, as well as the complexity of the ecosystem in the corridor of the Urip Sumoharjo-Perintis Kemerdekaan road. Furthermore, the instruments used in data tracing, namely field notes, in-depth interviews, documentation, and measurement of air pollution using mobile laboratory equipment, Aeroqual AQM60 Ambient Air Monitoring. The tools used for measuring air quality are in Figure 2 below.

Figure 2. Aeroqual AQM60 ambient air monitoring. Source: Author's elaboration.

The quantitative approach in this study emphasizes measuring results objectively and uses measurement data in the field. Furthermore, quantitative methods are used to collect a dataset in order to generalize and explain the phenomena developing in the field [57–59]. The measurement scale used is ordinal and interval. Furthermore, surveys are the main instrument used to collect data in the field. The results of the data obtained were then tested using statistical methods. A combination of qualitative and quantitative approaches in this study is presented in Figure 3 below.

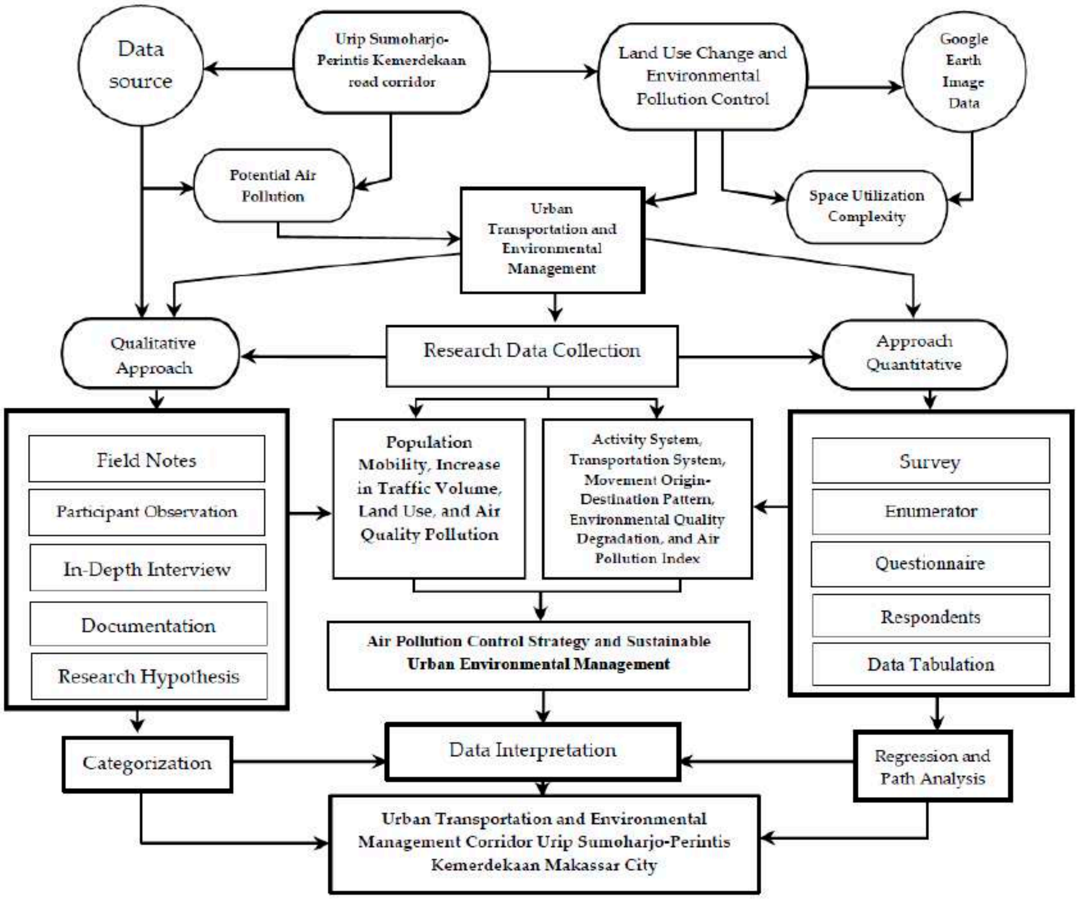

Figure 3. Flowchart of the methodology. Source: Author's elaboration.

3.2. Study Area

The study location is determined to be in the area of Makassar City. This road corridor is considered to have different specifications, when compared to other main road corridors in Makassar City, both in terms of land use and in terms of movement patterns of goods and passengers transport from Makassar City to Maros Regency and vice versa. The Urip Sumoharjo-Perintis Kemerdekaan road corridor, apart from functioning as the city's main road, plays a role in population mobility, and is a source of generating movement for freight and passenger transport. Furthermore, the land use pattern on the road corridor of Urip Sumoharjo-Perintis Kemerdekaan Makassar City is characterized by the existence of urban functions, among others; offices covering an area of 42.59 hectares, shops and shopping centers covering 100.12 hectares, education facilities covering 20.59 hectares, industry and warehousing covering 7.72 hectares, and housing and settlements covering 33.18 hectares. Thus, land use complexity is positively associated with ecosystem complexity. This means that the Urip Sumoharjo-Perintis Kemerdekaan road corridor is a destination for population movement with an average volume of vehicles during peak hours of 18,998 smpt/hour, with a volume of moving vehicles as high as 6332–8034 vehicles/day. The relatively high flow of transportation movement with a two-way system has an impact on the Urip Sumoharjo-Perintis Kemerdekaan road corridor, which has an impact on road capacity loads and high environmental pollution loads as well as the air quality pollution index. Urban air quality is currently a serious problem along with the increasing number of vehicles, thus requiring control and management [60].

Utilization of space, which tends to increase, has a positive contribution to increasing the generation and attractiveness of transportation and its impact on decreasing environmental quality. The considerations for selecting the study location on the Urip Sumoharjo-Perintis Kemerdekaan road corridor of Makassar City, include: (1) Sporadic changes in land use on the Urip Sumoharjo-Perintis Kemerdekaan road corridor due to weak control over spatial use; (2) the pattern of population mobility and traffic volume has increased from time to time; (3) the developing spatial pattern and the increase in the flow of transportation movements have a positive contribution to the decline in environmental quality and air quality pollution; (4) the management of the transportation system and air pollution in the Urip Sumoharjo-Perintis Kemerdekaan road corridor is oriented towards the sustainable development of Makassar City. Data on the number of motorized vehicles that utilize the Urip Sumoharjo-Perintis Kemerdekaan road corridor are in Table 4 and data on land use are in Table 5.

Table 5. Motor vehicle data on the Urip Sumoharjo-Perintis Kemerdekaan road corridor.

Number	Transportation Type													
	Sedan, Jeep, Station Wagon			Bus, Microbus			Trucks, Pick-Ups			Special Vehicles			Motorcycle	
	P	U	D	P	U	D	P	U	D	P	U	D	P	D
1	121,778	4305	1692	368	449	158	35,292	2914	608	30	1	2	530,156	5216
2	127,333	10,461	2443	887	421	218	38,038	2786	1247	234	13	48	705,988	13,081
Information	Personal/Black Plate (P)					General/Yellow Plate (U)				Service/Red Plate (D)				
	1. Normal Situation					2. Busy Hours								

Source: Authors' elaboration, Reference [61].

Table 5 shows the number of vehicles operating on the Urip Sumoharjo-Perintis Kemerdekaan Makassar City road corridor. The classification of vehicle types is divided into several categories, including: (1) 249,111 private cars (sedans, jeeps, and station wagons) with a classification of 121,778 normal situations and 127,333 during peak hours; (2) passenger transportation consists of buses and microbus consisting of three categories, namely (i) 1692 private transports in normal conditions and 2443 during peak hours; (3) goods transportation consists of trucks and pick-ups totaling 35,292 in normal situations and 38,038 during peak hours; (4) there are 30 special vehicles in normal situations and 234 vehicles during peak hours; and (5) 530,156 motorbikes in normal situations and 705,988 during peak hours. The high mobility of freight and passenger transportation is positively associated with air pollution on the Urip Sumoharjo-Perintis Kemerdekaan road corridor.

Table 6 shows the complexity of space utilization on the Urip Sumoharjo-Perintis independence road corridor. The three dominant land use categories, namely (i) commercial activities and services as much as 34.16%; (ii) 14.53% office activities; and (iii) 11.32% housing and settlement buildings. The complexity of spatial use illustrates that the function corridor of the Urip Sumoharjo-Perintis independence road corridor, besides functioning as connecting urban areas to the city center, also functions as a destination area. Furthermore, the growing complexity of space utilization contributes positively to environmental quality degradation and air quality pollution. The research locations are shown in Figure 4.

3.3. Method of Collecting Data

Data collection in this study was carried out from December 2019 to May 2020. The data collection was carried out through observations, surveys, air quality measurements, in-depth interviews, and documents.

3.3.1. Field Observation

Field observations in this study were carried out to observe changes in land use, traffic volume, types and modes of transportation, population mobility, patterns of origin, and destination of movement. Observations in this study used field notes, cameras, and a base map of the study location. The aim is to describe traffic conditions and characteristics, land use patterns, transportation movement systems, and their impact on environmental quality degradation and air pollution in the corridor of the Urip Sumoharjo-Perintis Kemerdekaan of Makassar City.

Table 6. Land use data on the Urip Somoharjo-Perintis Kemerdekaan road corridor.

Number	Land Use	Large (Hectares)	Percentage (%)
1	Mixed Use	10.45	3.56
2	Artificial Lake	1.31	0.45
3	Industrial and Warehousing	7.72	2.63
4	Canal	0.49	0.17
5	Health Facilities	4.99	1.70
6	Commercial and Services	100.12	34.16
7	Military	23.03	7.86
8	Sport Facilities	0.43	0.15
9	Graveyard	4.23	1.44
10	Educational Facilities	20.59	7.02
11	Religious Facilities	2.79	0.95
12	Offices	42.59	14.53
13	Settlement	33.18	11.32
14	Shrubs	38.41	13.11
15	Rivers	1.43	0.49
16	Ponds	1.00	0.34
17	Park	0.35	0.12

Source: Authors' elaboration.

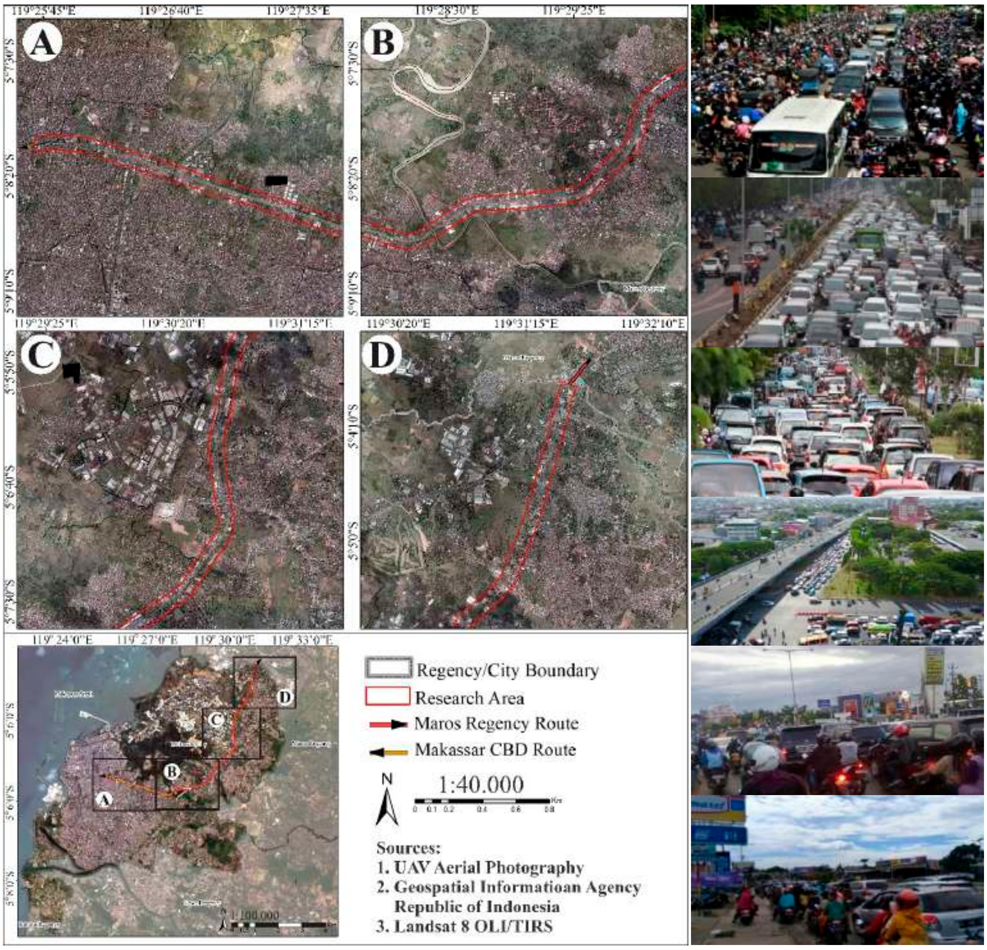

Figure 4. Corridor of Urip Sumoharjo-Perintis Kemerdekaan. (**A**) Commercial, Office, and Education Area; (**B**) Tallo Power Plant and Education Area; (**C**) Daya Traditional Market and Industry; (**D**) The main route is Hasanuddin International Airport.

3.3.2. In-Deep Interview

The main subject of this study is the population mobility based on the mode of transportation used. The in-depth interview function was carried out. In-depth interviews in this study were conducted for the purpose of establishing an understanding of the limited environment of the development in the field. In-depth interviews in this study required the use of tools such as a tape recorder, drawings, and interview guides, which included freelance notes, checklists, and grade scales. In-depth interviews in this study were focused on extracting information from quantitative data results. An interview guide based on the results of respondents' answers and according to the phenomena that are the focus of this research was used for the in-depth interviews. In-depth interviews in this study focused on users of transportation modes, which were differentiated based on the type of vehicle used to travel for work, economic, and social interests. In-depth interviews were conducted for three time categories, namely 07.00–08.00 in the morning, 12.00–13.00 h in the afternoon, and 17.00–18.00 h in the afternoon.

3.3.3. Questionnaire

The questionnaire in this study is used to collect data on population mobility based on origin and destination, traffic volume data collection, and the characteristics of the transportation used by the community. In addition, the questionnaire was also used to collect data on various developing activities and patterns of community activity based on respondents' perceptions. The purpose of using a questionnaire in this study is to describe situations and phenomena that develop in the field. Furthermore, filling out the questionnaire in this study was carried out by enumerators who were previously selected. The criteria for filling out the questionnaire (respondent) are divided into two categories: (1) Residents who travel on the road corridor of Urip Sumoharjo—Perintis Kemerdekaan based on the purpose of the trip, namely economic and social interests and (2) local residents who have economic businesses and live in communities along the Urip Sumoharjo-Perintis Kemerdekaan corridor. The questionnaires were distributed to strategic locations and centers of socio-economic activities.

3.3.4. Documentation

Documents are records of events that are already valid. Thus, this study uses various study results related to the situation and condition of the transportation movement system in the Urip Sumoharjo—Perintis Kemerdekaan Makassar City road corridor. The documents referred to, among other things, traffic volume data, data on the types and modes of transportation, and profiles of population trips, and other documents related to the objectives of the study were obtained through the Central Bureau of Statistics, the Department of Transportation, and the Makassar City Regional Development Planning Agency.

3.3.5. Triangulation

Triangulation in the study was carried out for three main categories, namely: (1) Validation of data obtained from observations, in-depth interviews, and surveys; (2) extension of observation time to find specific matters related to environmental quality degradation and air pollution; (3) the data that have been collected in the field is then confirmed again from various sources for the purpose of formulating field findings, by testing the information using different methods. Thus, the triangulation in this study is intended to clarify information obtained in the field from different sources. The data collected and the methods are shown in Table 7.

Table 7. Summary of research data and data collection methods.

Number	Research Question	Research Variable	Indicator	Method of Collecting Data	Tools Used
1	The effect of population mobility, increased traffic volume, and land use on air quality pollution.	Population Mobility	Population mobility is measured by origin of movement, purpose of travel, distance, costs used, and ease of travel.	Observation and survey	Field notes and handy tally counter
		Traffic Volume	Traffic volume is measured by traffic flow, type of vehicle, vehicle speed, road capacity, and degree of saturation.	Observation and survey	Field notes and handy tally counter
		Land Use	Land use is measured by spatial function, space utilization, land use, and spatial activity patterns.	Observations, surveys, and in-depth interviews	Base Map, Field Notes, Recorder and Camera.
		Air Quality Pollution	Air quality pollution is measured by air pollutant index, air temperature and humidity, city activities and transportation activities, and the quality of Carbon Monoxide (CO), Nitrogen (NO_2), and Sulfur Dioxide (SO_2), and Total Suspended Particulate (TSP).	Observation, survey, and measurement of air pollution	Field Notes, Camera, and AQM60
2	The direct and indirect effects of urban activity systems, transportation systems, and origin-destination movement patterns on environmental quality degradation and the air pollution index.	City Activity System	City activity system measured by land use patterns, space allocation, population density, and building density.	Observation and survey	Field notes and Base Map
		Transportation System	The transportation system is measured by security, comfort, timeliness, transportation costs, transportation facilities and infrastructure.	Observation and survey	Field Notes, Questionnaires, and Base Maps
		Origin and Purpose of Movement	The origin and destination of movements are measured by availability of transportation mode, travel distance, and travel time	Observation and survey	Field notes, questionnaires and cameras
		Environmental Quality Decrease	Environmental quality degradation is measured by pollution load, pollution level, and increase in gas emissions	Observation and survey	Field notes, Questionnaires, MG811 sensors, and cameras
		Air Pollution Index	Air pollution index is measured by green index, carbon monoxide index, sulfur dioxide index, and particulate carbon index	Observation, survey and measurement of air pollution	Field notes, questionnaires, data entry format, camera, and Integrated Air Quality Detector
3	Air pollution control strategies and sustainable urban environmental management.	Air Pollution Control	Air pollution control is measured by pollution management and air pollutant index categorization	Observation, survey and measurement of air pollution	Field notes, questionnaires, data entry format, camera, and AQM60
		Environmental Management Sustainability	The sustainability of environmental management is measured by air pollution index, transportation management, community participation, green infrastructure, and green transportation.	Observation and survey	Field notes, AQM60, Questionnaires, and Base Maps

Source: Authors' elaboration.

3.4. Population and Research Sample

The population is a generalization area consisting of objects or subjects that have certain qualities and characteristics that are determined by the researcher for studying and drawing conclusions [58]. Thus, the population in this study is land use, transport users, population mobility, and traffic volume. The quantitative data in this study are data obtained from the survey results from the sample. Furthermore, the sample in this study was determined using a purposive sampling method. Purposive sampling is a nonrandom sampling technique, in which the researcher determines sampling by determining specific characteristics, in accordance with the research objectives, so that it is expected that research problems can be answered. Non-random sampling means that it is a sampling technique that does not provide equal opportunities for every member of the population to be a research sample [62,63]. The use of purposive sampling method in the study is based on the following considerations: (1) The criteria or limits are carefully defined; (2) the sample taken as the research subject is a sample that meets the predetermined criteria. The criteria considers (i) the population considered mobile, (ii) the mode of transportation used, (iii) travel orientation and purpose, and (iv) people who live permanently at the research location for at least 5 years and engage in certain types of business and activities. Furthermore, the completed questionnaires were then analyzed. The samples in this study used the Sloving method [64], with the following formulations:

$$N = n/N(d)^2 + 1 \quad (1)$$

N is the study population, n is the sample, and d is a precision value of 95% or 0.05. The number of samples determined in this study was 400 samples.

3.5. Method of Analysis

The data analysis in this study used quantitative and qualitative methods, which were carried out sequentially. The results of qualitative data were categorized and interpreted based on the facts found in the field. Furthermore, the data obtained through the results of the questionnaire were then grouped and tested using statistical methods. Qualitative data analysis was carried out by means of data reduction, display data, and drawing conclusions. The quantitative analysis was carried out using descriptive, associative, and correlational statistics. Transportation analysis in this study considers traffic volume analysis methods, road capacity, and the degree of saturation. The formulation of the transportation system analysis is as follows:

$$q = n/t \quad (2)$$

$$C = Co + FC_w + FC_{sp} + FC_{sf} + FC_{cs} \quad (3)$$

$$DS = Q/C \quad (4)$$

where q is the volume of the traffic passing through a certain point, n is the number of vehicles passing that point in the observation time interval, and 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_{sf} 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). Furthermore, the air pollution index uses the air quality index analysis method, i.e., the carbon monoxide index, the sulfur dioxide index, the particulate carbon index, the nitrogen dioxide index, the oxidant index, the extreme value index, and the national quality index. The air pollution standard index refers to three important parameters: (1) The ambient concentration is expressed in (X_x) in units of ppm, mg/m^3 and others; (2) the real number of the air pollutant standard index is stated in (I); and (3) the procedure for determining the value of the

ISMU refers to the Government Regulation of the Republic of Indonesia Number 4 of 1999 concerning Air Pollution Control. The formulations used in the calculations are as follows:

$$\mathrm{I} = \frac{\mathrm{I_A} - \mathrm{I_B}}{\mathrm{X_A} - \mathrm{X_B}}(\mathrm{X_X} - \mathrm{X_B}) + \mathrm{I_B} \quad (5)$$

$$\text{ISM Value} = \frac{(3 \times \text{Skr CO}) + (2 \times \text{Skr PM}) + (2 \times \text{Skr NO}_2) + (2\ \text{Skr SO}_2)}{9} \quad (6)$$

I is the calculated indeks standar air pollutant, I_A is the upper limit indeks standar air pollutant, I_B is the lower limit indeks standar air pollutant, X_A is the upper limit ambient, X_B is the lower limit ambient, and Xx is the real ambient level measured. Furthermore, the Air Quality Standard Index (AQSI) is an indicator that shows the value of the air quality, CO is the index value of carbon monoxide pollution, NO_2 is the index value of nitrogen, and SO_2 is the index value of sulfur dioxide.

The multiple linear regression method was used to answer the question of the effect of population mobility, increased traffic volume, and land use on air quality pollution. The variables are (i) X_1 (population mobility), X_2 (traffic volume), X_3 (land use), and Y (environmental pollution). Furthermore, Pearson's correlation coefficient is used to measure the strength and direction of the linear relationship of two or more variables. In this case, the research data obtained are an interval scale. Path analysis in this study was used with the following considerations: (1) Interval scale research metric data; (2) there are exogenous independent variables and endogenous dependent variables for multiple regression models and intermediate variables for mediation models and combined models of mediation and multiple regression and complex models; and (3) the sample size used is 400. The effect of variables using multiple linear regression methods, correlation, and path analysis was tested using the following equation:

$$\mathrm{Y = a + b_1X_1 + b_2X_2 + \ldots + b_nX_n} \quad (7)$$

$$r_{xy} = \frac{N\sum X_i y_i - \sum X_i \sum y_i}{\sqrt{N\sum X^2{}_i - (\sum X^2{}_i)^2}\ \sqrt{N\sum y^2{}_i - (\sum y_i)^2}} \quad (8)$$

$$\mathrm{Y = PYX_1 + PYX_2 + PYX_3} + \varepsilon \quad (9)$$

Y is the dependent variable (predicted value), X_1, X_2, and X_3, the independent variable, a is a constant (the value of Y if X_1, X_2, X_3 ... Xn = 0), b is the regression coefficient (value of increase or decrease). r_{xy} is the validity coefficient, N is the amount of data, X is the comparison value, and Y is the value of the instrument to be validated. The path analysis application in the study is based on variables, namely (i) X_1, exogenous independent variable (activity system), (ii) X_2, exogenous independent variable (transportation system), (iii) X_3, exogenous independent variables (origin and destination of movement), (iv) Y, endogenous dependent variable (environmental degradation), and (v) Z, endogenous dependent variable (air pollution index). Path analysis is presented in Figure 5 below.

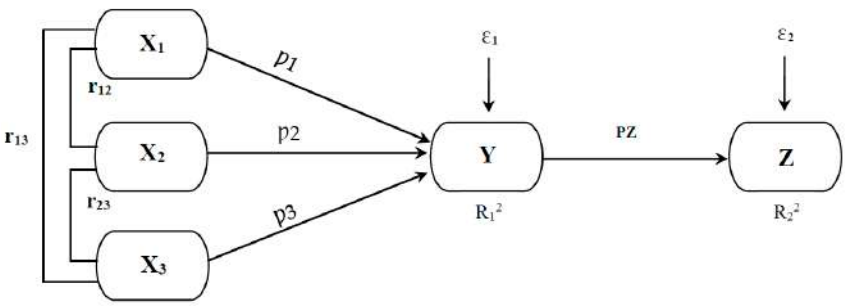

Figure 5. Model of path analysis.

Figure 5 shows the path analysis model with the following explanations: (1) There is a correlation or calculated correlation between the independent variables (there is a relationship between variables

X_1, X_2, and X_3); (2) the magnitude of the relationship is expressed by the correlation coefficient (r_{12}), (r_{13}), and (r_{23}), where (r_{12}) is the correlation or relationship between X_1 and X_2, (r_{13}) is the correlation or relationship X_1 and X_3, (r_{23}) is correlation or relationship between X_2 and X_3; (3) the variables X_1, X_2, and X_3 act as independent variables affecting the dependent variable (Z) through the intervening variable (Y), that is, the effect of X_1, X_2, and X_3 on Z is not direct, but through intermediary or intervening Y, so that X_1, X_2, and X_3 affect Y, then Y affects Z. Furthermore, the independent variable X_1 and the intervening variable Y are connected by the regression coefficient (p_1), the independent variable X_2 and the intervening variable Y are connected by the regression coefficient (p_2), the independent variable X_3 and the intervening variable Y are connected by the regression coefficient (p_3); (4) the direct effect of X_1 on Y is the square of the regression coefficient (p_{12}), the direct effect of X_2 on Y is the square of the regression coefficient (p_{22}), the direct effect of X_3 on Y is the squared of the regression coefficient (p_{32}). The magnitude of the coefficient of determination is denoted by the symbol R^2, which is the magnitude of the total effect, namely the value of the total effect of the independent variables under study on the dependent variable. For the case of this model, the total effect is divided into two categories, namely (i) $R_1{}^2$ is the total effect (both direct and indirect) X_1, X_2, and X_3 on Y, (ii) $R_2{}^2$ is the total effect of Y on Z; (5) epsilon (ε) states the amount of residual effect, namely the magnitude of the influence of other variables, which can affect the intervening variable and the dependent variable but is not researched; the residue in this model is written with the symbols ε_1 and ε_2. The coefficient of determination in this model uses the following formulation.

$$R_1{}^2 = [p_1{}^2 + p_2{}^2 + p_3{}^2] + [(p_1.r_{12}.\ p_2) + (p_2.r_{12}.\ p_1)] + [(p_1.r_{13}.\ p_3) + [p_2.r_{23}.\ p_3) + (p_3.r_{23}.\ p_2)]$$
$$R_2{}^2 = p_3{}^2. \quad (10)$$

$R_1{}^2$ is the total effect (direct effect + indirect effect) X_1, X_2, and X_3 on Y [$p_{12} + p_{22} + p_{32}$] is the direct effect of X_1, X_2, and X_3 on Y, ($p_1.r_{12}.\ p_2$) is the indirect effect variable X_1 through X_2 on Y, ($p_1.r_{13}.\ p_3$) is the indirect effect of variables X_1 through X_3 on Y, ($p_3.r_{13}.\ p_1$) is the indirect effect of X_3 through X_1 on Y, ($p_2.r_{23}.\ p_3$) is the indirect effect of variables X_2 through X_3 on Y, ($p_3.r_{23}.\ p_2$) is the indirect effect of variables X_3 through X_2 on Y, and $R_2{}^2$ or p_{32} is the direct effect of Y on Z.

Furthermore, to answer the third research question, regarding air pollution control strategies and sustainable urban environmental management, the SWOT analysis method was used. The strategy formulation and sustainability of urban environmental management in this study are linked to the development policy of Makassar City. SWOT analysis is based on (i) strengths, (ii) weaknesses, (iii) challenges, and (iv) opportunities. SWOT analysis is the systematic identification of various factors that are used to formulate a strategy. This analysis will logically maximize strengths and opportunities, which are simultaneously considered to minimize weaknesses and threats against environmental control and management in the future. The strategic decision-making process is always related to the development of mission, objectives, strategies, and policies. Swot analysis is presented in Table 8 below.

Table 8. SWOT analysis matrix.

	External Factors		
	Identification of Factor	Opportunity (O)	Threat (T)
		Determine the opportunity factors	Determine the threat factors
Internal Factors	Strength (S)	S to O	S to T
	Determine the strength factors	Determine the program that emerges by matching strength (S) with opportunity (O)	Determine the programs that emerge by matching strength with threat
	Weakness (W)	W to O	W to T
	Determine the factors of weakness	Determine the emerging program by matching weakness (W) with opportunity (O)	Determine the emerging program by matching weakness (W) with threats (T)

Source: Reference [65].

4. Results

4.1. Population Mobility, Land Use, and the Air Pollution Index

Population mobility in relation to the movement system in the Urip Sumoharjo-Perintis Kemerdekaan road corridor is assessed based on the pattern of travel origin and destination. Six zones affect the high movement of the Urip Sumoharjo-Perintis Kemerdekaan road corridor: (i) Residential centers, (ii) office centers, (iii) trade centers, (iv) education centers, (v) industrial centers, and (vi) the Sultan Hasanuddin international airport. The six spatial zones formed have a positive contribution to increase population mobility and use of transportation modes of transportation. Furthermore, four important factors influence the formation of spatial zoning, namely population density, road network, built-up area, and the ratio of green coverage to spatial distribution [66,67].

The complexity of developing land uses not only has an impact on the relatively high movement of transportation, but also contributes positively to environmental degradation. The decline in environmental quality that is quite prominent in the corridor of the Urip Sumoharjo-Perintis Kemerdekaan road is marked by the difference in land height between commercial buildings, offices, educational facilities, and health facilities on the existence of housing and settlements. The direct impact that can be observed shows that, along the Urip Sumoharjo-Perintis Kemerdekaan road corridor, there is a potential threat of flooding that occurs every year. The land use in the Urip Sumoharjo-Perintis Kemerdekaan road corridor is shown in Figure 6.

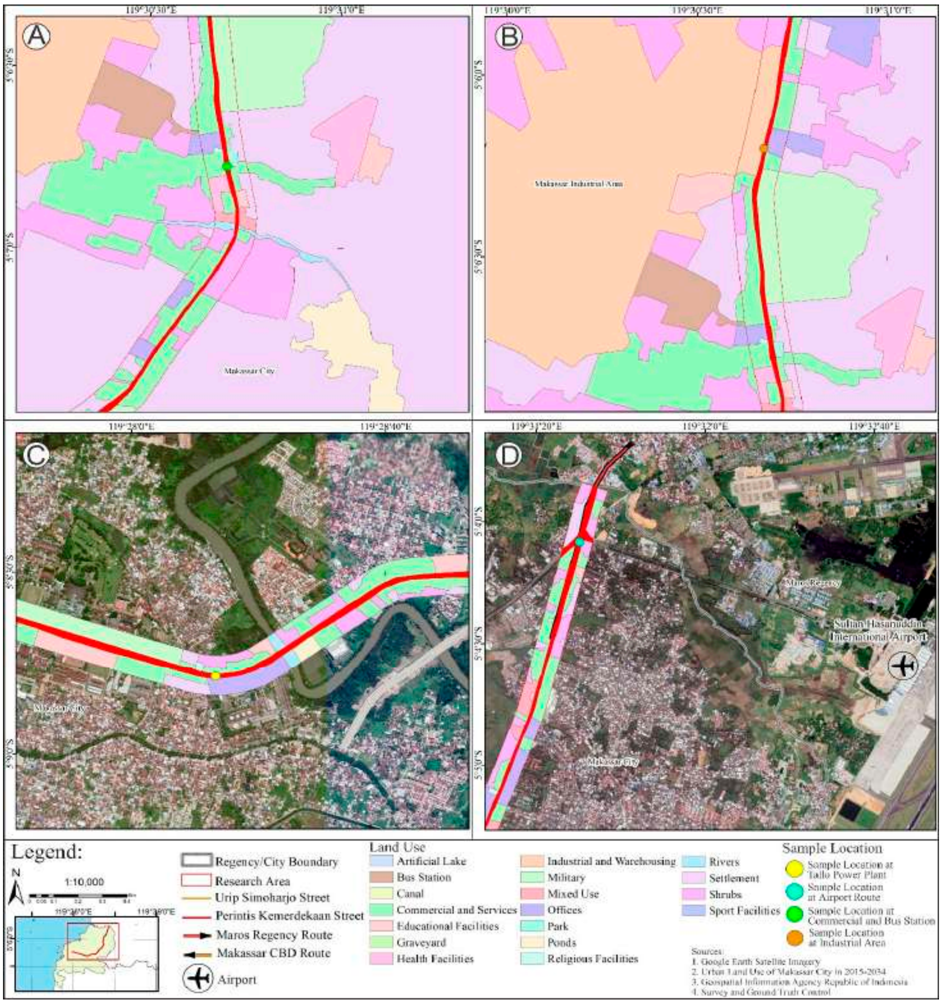

Figure 6. (**A**) Commercial and Bus Station, (**B**) Industrial area, (**C**) Tallo power plant, and (**D**) Bandara Route. Land use in the corridor of Urip Sumoharjo-Perintis Kemerdekaan Makassar City. Source: Author elaborator.

The complexity of the use of space (see Figure 6) illustrates the functions of activities that develop in the corridor of the Urip Sumoharjo-Perintis Kemerdekaan of Makassar City. Interpretations that can be submitted regarding the use of developing space include: (1) Along the Urip Sumoharjo corridor marked by several activity functions that become the embryo of growth, including: (a) Makassar City regional government office center, (b) Sulawesi Provincial governor's office South, (c) shopping centers with a city service scale, (d) education centers (universities), (e) private hospitals, (f) shopping centers, cafes, and restaurants, and (g) military and police offices; (2) along the Perintis Kemerdekaan road corridor marked by the existence of several activity functions, including: (a) Shopping centers, (b) PLTU Tallo power plant and Sermani industry, (c) education centers (colleges), (d) market centers traditional-modern Daya and regional terminals, (e) Makassar industrial area (KIMA), (f) shopping centers, cafes, and restaurants, and (g) government offices and private offices; (3) the existence of housing and settlements that are in direct contact with the functions of economic and social activities. Thus, the complexity of land use at Urip Sumoharjo-Perintis Kemerdekaan directly resulted in increasing population mobility towards a decrease in environmental quality and air pollution.

The direct effect of the transportation movement system on the Urip Sumoharjo-Perintis Kemerdekaan road corridor on the increase in traffic volume is divided into four categories: (a) Attraction and movement generation, (b) the distribution of movement, (c) the choice of mode of transport, and (d) selection route. For cities, there are many challenges resulting from the complex definition of a sustainable urban freight system [68]. Furthermore, the pattern of origin and destination of movement in the Urip Sumoharjo-Perintis Kemerdekaan corridor is influenced by three important elements: (i) The purpose of the movement, (ii) the time of movement, and (iii) the mode of transport used. The results of the field confirmation illustrate that differences in the dominant mode of transportation used by residents in mobility are directly related to the function of space that is developing and dominant using private vehicles and motorbikes. Thus, urban transportation policy is not related to developing spatial patterns, so that it has an impact on changes in long-term socio-spatial structure [69,70]. The field facts found show that high traffic volume and a lack of proportionality with the capacity of the road has an impact on the slowing of the flow of vehicles and in peak hours; i.e., the morning between 8:30 and 10:00 and the afternoon between 17:00 and 18:00 presents a fairly high flow of transportation movements causing traffic jams on the Urip Sumoharjo-Perintis Kemerdekaan road corridor. Movements between the zones and modes of transport in mobility are shown in Figure 7.

Figure 7A shows the movement pattern and mode of transportation used to get to the destination. A percentage of 38.79% of the mobility of the population for the purpose of going to offices is by motorbike, and 26.24% is by private cars. The mobility of the population for the purpose of trading activities and to the business center shows the same thing: 31.86% using motorbikes and 29.09% using private cars. The ease of accessibility in supporting population mobility for the purpose of working in offices, trading, and shopping is strongly influenced by the distance factor. Urban sustainability standards by improving public transport, encouraging non-motorized modes, zoning pedestrians, limiting private car use, and otherwise trying to undo the urban transformation caused by car domination [71,72]. Field facts that have been found indicate that the choice to use private transportation in addition to the distance factor is also influenced by factors of comfort, safety, and timeliness to the destination. Thus, the inconvenience, safety, and effectiveness of reaching the destination are a consideration for the community to use public transportation modes. In the context of transit-oriented city development (TOD), it has become a model to meet various local and regional goals, namely increasing mobility, increasing passengers, attracting investment, improving quality of life, and encouraging sustainable urban integration [73,74]. Furthermore, choice to use a motorbike for work and trade purposes avoids congestion and allows one to reach one's destination on time, especially during peak hours. Thus, traffic congestion cannot be avoided due to traffic volume exceeding the capacity of the road body, so it is very important to solve it immediately [75].

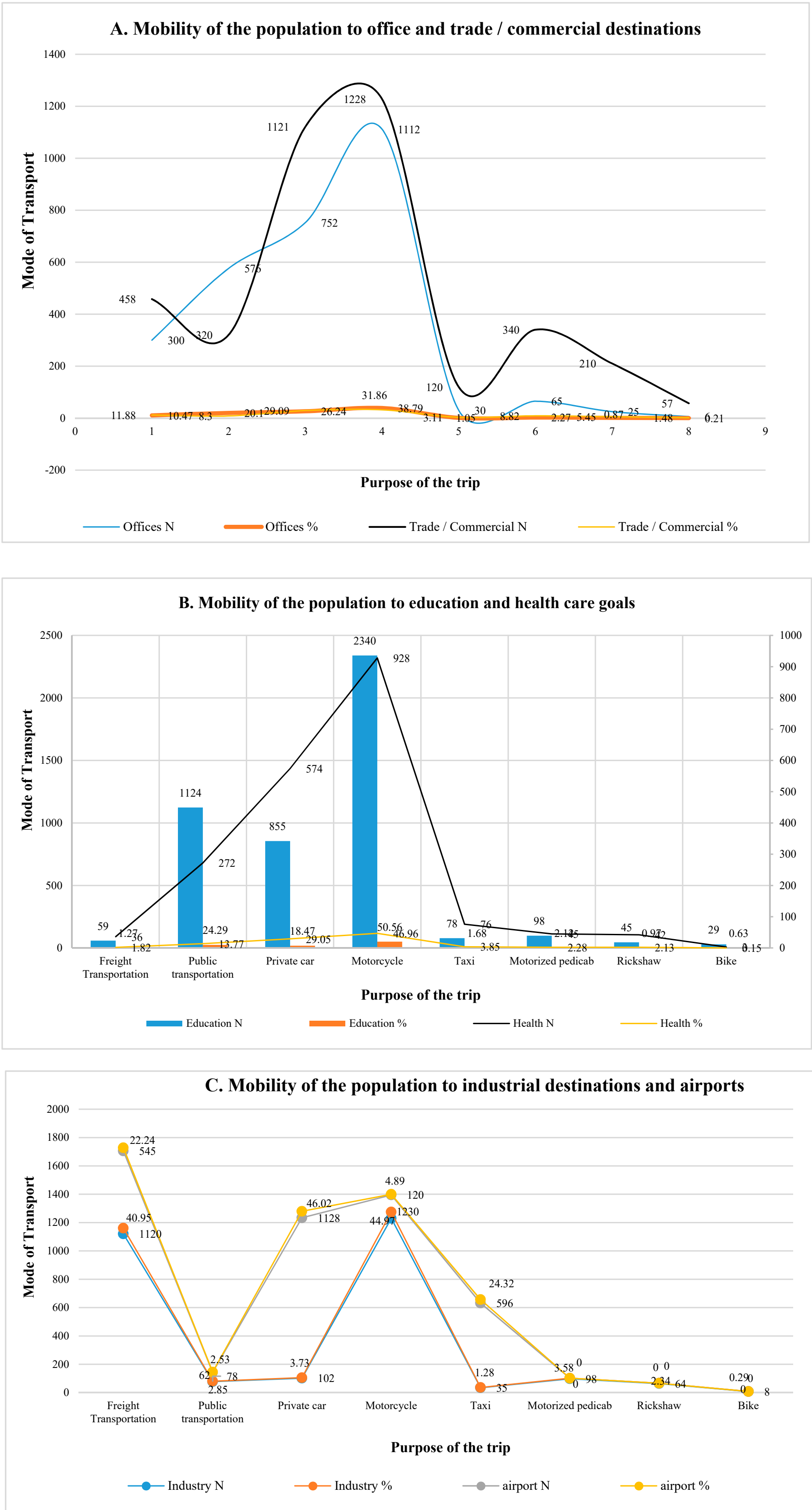

Figure 7. (**A**–**C**) Population Mobility. The use of transportation modes is based on the purpose of travel on the road corridor Urip Sumoharjo—Perintis Kemerdekaan Makassar City. Source: Primary data.

Figure 7B shows the mobility of the population in obtaining education and health services. Regarding the use of transportation modes, 50.56% of the population chose to use motorbikes, and 24.29% of the population chose to use public transportation. The choice of transportation mode for the purpose of traveling to health facility locations was motorbikes 46.96% of the time and private cars 29.05% of the time. The field facts show that the use of motorbikes for educational purposes is influenced by the efficiency of travel time and the economic costs, in addition to the ease of getting to their destination. This means that trips to educational locations are dominated by students and groups of students. Furthermore, the choice of using motorbikes and private cars for the purpose of traveling to health facilities is not only influenced by the efficiency of travel time and the economic costs but also by the distance to the destination location. Thus, the transportation sector is currently facing a transition, in this case urban passenger transportation [76].

Figure 7C shows the preferred mode of transport for the purpose of travel to industrial sites and Hasanuddin International Airport. Interpretations that can be submitted regarding the choice of mode are (i) 44.97% of the modes of transportation used by residents for the purpose of working in industrial activities and 3.73% using private cars. This difference illustrates that the choice of mode of transportation to work in the industrial sector is strongly influenced by the level of community income. (ii) Industrial activities that are oriented towards the supply of raw materials and distribution of production marketing show the use of goods transportation facilities as much as 40.95%. The process of transporting goods is reciprocal from the location of raw materials to industrial locations and from industrial locations to market locations (consumers). The use of self-driving trucks is a solution to solving problems facing the industry today [77]. Furthermore, the choice of mode of transportation to the airport is divided into three categories: (i) Private cars are used as much as 46.02% of the time. This choice is very much influenced by the timeliness of arriving at the destination. (ii) Taxis are used 24.32% of the time. This choice is made by residents as an alternative and time efficiency to reach the destination area. (iii) Goods transportation is done 22.24% of the time, from the direction of the airport and vice versa, showing that airports, in addition to providing passenger transportation, function in the operation of goods transportation. Large transport terminals, particularly ports and airports, confer the status of gateways or hubs to their location since they become obligatory points of transit between different segments of the global transport system [78].

Figure 7A–C illustrate that population mobility based on the choice of mode of transportation has an impact on the generation and attraction of transportation leading to increasing traffic volume, ecosystem complexity, and the resulting air pollution. Air pollution, which spreads rapidly with a strong diffusive capacity, impacts the environment, climate, and public health [79]. Furthermore, the traffic volume that tends to increase on the Urip Sumoharjo-Perintis Kemerdekaan road corridor is closely related to developing land use and constitutes an inseparable unit. Furthermore, changes in land use over a long period of time have a positive contribution to the decline in the quality of the urban environment [80]. Thus, land use requirements are one of the factors determining the movement of transportation systems based on patterns of origin and destination of movement. The dominant activities in this corridor, i.e., the functions of commercial, education facilities, offices, industry, trade, services, and airports, have a positive contribution to traffic volume in relation to the capacity of the road body in the Urip Sumoharjo-Perintis Kemerdekaan corridor. Furthermore, accessibility tends to increase, which is positively associated with land use values, and contributes positively to increased air pollution leading to a decrease in environmental quality. The magnitude of the spillover effects of air pollution is larger than the negative direct effects on local cities [81].

The results of field observations illustrate that the dominant spatial function develops in the road corridor of the Urip Sumoharjo-Perintis Kemerdekaan, including: (1) The dominant commercial functions, namely shops, cafes, restaurants, and shopping centers occupy an area of 100,12 hectares; (2) industrial functions are marked by the presence of the Sermani industry, the steam power plant (PLTU), and the Makassar industrial area (KIMA), occupying an area of 7.72 hectares; (3) the functions of education facilities are marked by the existence of universities (UNIBOS, UMI, UNIFA, UNHAS, STIMIK, Al GASALI, UKI Paulus) and other universities, with a land area of 20.59 hectares utilized; (4) office functions are marked by the existence of several government offices (Combined Makassar City Government offices, South Sulawesi Provincial Governor Office) and several private offices, and the area of land utilized is 43.59 hectares; (5) changes in land use in the corridor Urip Sumoharjo-Perintis Kemerdekaan road have an impact on increasing the generation and attraction of trips based on spatial functions that develop the complexity of the movement system and the complexity of the ecosystem. Thus, the challenge in ecosystem management is the complex interaction between humans and the natural environment as a single system [82–84]. Therefore, an in-depth study of its relationship with ecosystem services is needed by integrating human and natural systems, namely social, economic, and environmental interactions [85].

Increased population mobility, in line with the demand for transportation services and the complexity of space utilization in the Urip Sumoharjo-Perintis Kemerdekaan corridor, has a direct impact on the air pollution index. Measurement of the air pollution index was carried out at four sampling points: (i) The Tallo river area, marked by the presence of an air power plant (PLTU) and Sermani Industry activities, (ii) the Daya economic activity center and the Daya terminal, (iii) the Makassar (KIMA) industrial area, and (iv) the Hasanuddin International Airport. Measurement of the air pollution index at the four locations was performed using AMQ60 (Ambient Air Monitoring). The location of the sample points is shown in Figure 8, and the results of the measurement of the air pollution index are shown in Tables 9–11.

Table 9 shows the results of air quality measurements at four sampling locations on the Urip Sumoharjo-Perintis Kemerdekaan road corridor. The highest pollutant content for the Carbon Dioxide (CO_2) category is located in the Makassar industrial area (KIMA). The levels of the air pollutants consisting of dust, smoke, and vapor particles are in two locations: In the Makassar industrial area (KIMA) and in the Daya business center and the Daya regional terminal. Nitrogen Dioxide (NO_2) pollutant levels are located in the Makassar industrial area (KIMA). The highest pollutant content is for the Sulfur Dioxide category (SO_2) and is predominantly located around the PLTU power plant and the Sermani Industry. The results of the air quality evaluation using the indeks standar air pollutant indicator at the four test point locations are shown in Table 10.

Table 10 shows the ISPU value for each air pollutant sampling point location. Three locations are in the dangerous category and are at the environmental threshold: The power business center and the power terminal, with a value of 504.24, the location of the PLTU power plant and the Sermani Industry, with a value of 360.36, and the location of the Makassar industrial area (KIMA), with a value of 511.8. The indeks standar air pollutant value at the Hasanuddin International Airport location is 119.814, which in the unhealthy category. The air quality standard index values for the four sampling categories are shown in Table 11.

Table 9. The results of air quality measurements at four sample point locations.

Location	**Parameter**			
	CO (BM = 30,000 µg/Nm^3)	**TSP (BM = 230 µg/Nm^3**	**NO_2 (BM = 400 µg/Nm^3)**	**SO_2 (BM = 900 µg/Nm^3)**
Business Center and Daya Terminals	168.08	156.31	40.85	25.14
PLTU Power Plant and Sermani Industry	120.12	96.63	88.20	65.19
Makassar Industrial Estate (KIMA)	170.60	160.45	118.05	35.75
Hasanuddin International Airport	39,938	29,554	21,963	21,413

Source: Primary data.

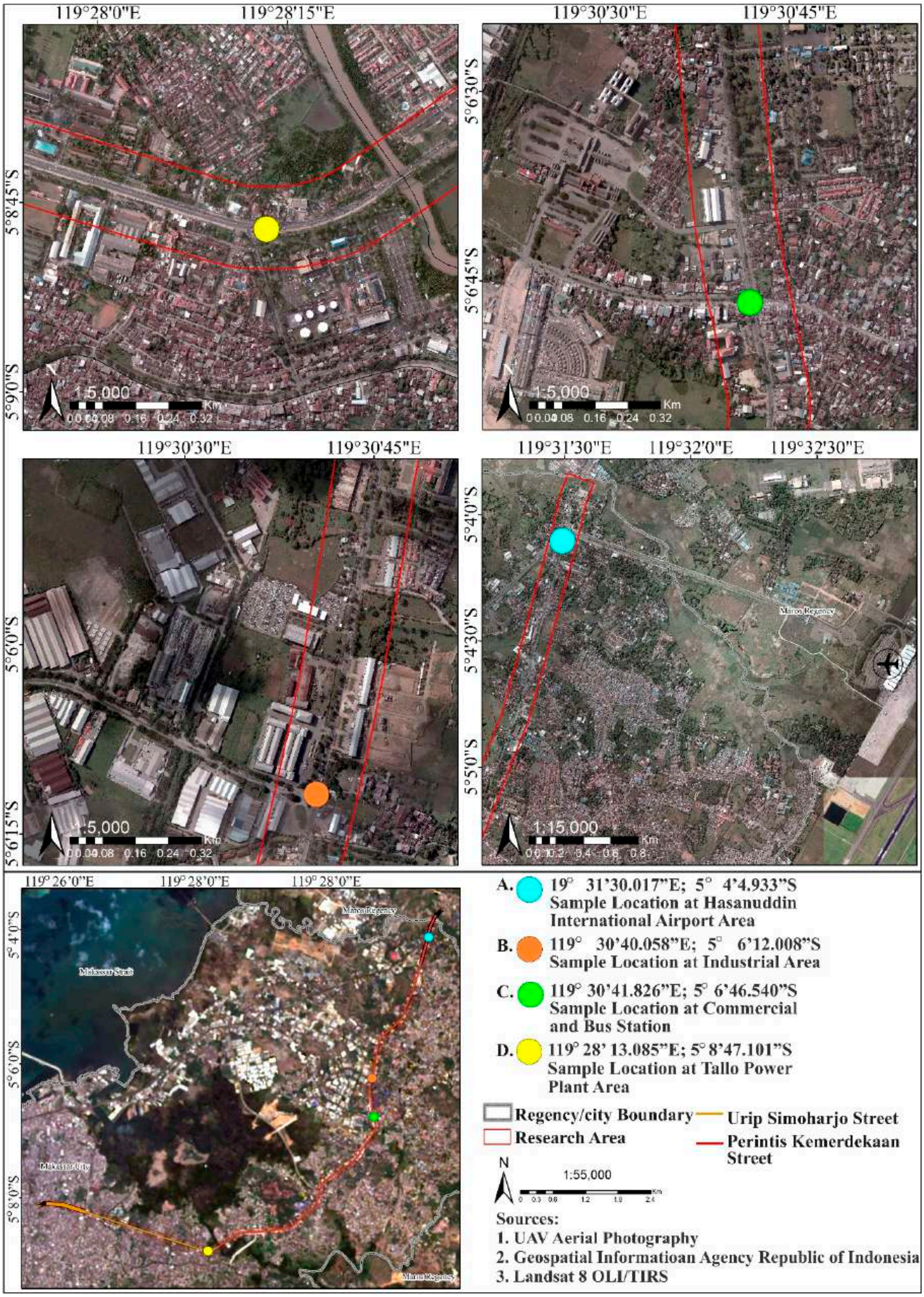

Figure 8. Location of sample points for measuring the air quality index of the Urip Sumoharjo-Perintis Kemerdekaan road corridor. Source: Authors' elaboration.

Table 10. Indeks standar air pollutant values at four sample point locations.

Location	Parameter					
	CO (BM = 30,000 µg/Nm^3)	TSP (BM = 230 µg/Nm^3	NO_2 (BM = 400 µg/Nm^3)	SO_2 (BM = 900 µg/Nm^3)	Highest Indeks Standar Air Pollutant Value	Indeks Standar Air Pollutant Status
Business Center and Daya Terminals	504.24	312.62	81.7	50.14	504.24	Dangerous
PLTU Power Plant and Sermani Industry	360.36	193.26	176.4	130.38	360.36	Dangerous
Makassar Industrial Estate (KIMA)	511.8	320.9	236.1	71.5	511.8	Dangerous
Hasanuddin International Airport	119,814	59,108	43,926	42,826	119,814	Not healthy

Source: Analysis results.

Table 11. Air quality standard index values at four sample point locations.

Location	Score Each Parameter					
	CO (BM = 30,000 µg/Nm^3)	TSP (BM = 230 µg/Nm^3)	NO_2 (BM = 400 µg/Nm^3)	SO_2 (BM = 900 µg/Nm^3)	Air Quality Standard Index Value	Air Quality Standard Index Status
Business Center and Daya Terminals	0.01	1.36	0.20	0.06	0.18	Polluted
PLTU Power Plant and Sermani Industry	0.01	0.84	0.44	0.14	0.16	Polluted
Makassar Industrial Estate (KIMA)	0.02	1.40	0.59	0.08	0.23	Heavy Contaminated
Hasanuddin International Airport	0.00	0.26	0.11	0.05	0.04	Not Polluted

Source: Analysis results.

Table 11 shows that the air quality standard index value of the business center and Daya terminal is 0.18, that of the PLTU and Sermani industrial power plants is 0.16, that of the Makassar industrial area (KIMA) is 0.23, and that of Hasanuddin International Airport is 0.04. This figure confirms that the business center and Power Terminal, and the PLTU Power Plant and Sermani industry, are polluted, and the Makassar industrial area (KIMA) is heavily polluted. The International Airport is not polluted. These results confirm that air pollution at the four locations is directly related to the exhaust gases produced by motorized vehicles due to the high volume of traffic. The emission intensity of different modes of transportation was estimated, and measures have been proposed to prevent and control air pollutants emitted from transportation [86]. The poor air quality at the four sampling locations confirmed that the land use activities were very complex, and the traffic volume was high enough that the air quality pollution in the Urip Sumoharjo-Perintis Kemerdekaan corridor was categorized as polluted. Thus, air pollution is a result of the complexity of land use and transportation movement systems and their effects on ecosystem conditions [87].

The facts found in the field illustrate the high level of air pollution in the Urip Sumoharjo-Perintis Kemerdekaan road corridor, which confirms that the average disease experienced by people is asthma, ispa, and bronchitis. This means that the air pollution load, which is quite high in the unhealthy and very unhealthy categories, has a direct effect on the health of the local community. Dominant air pollution is generated from various sources, namely motor vehicle fumes, power generation facilities, industrial processes, and housing [88–91]. Furthermore, economic growth, industrialization, urbanization, increasing population, energy consumption, transportation, and motorization are the trigger factors for increased air pollution [92]. Thus, air pollution is a serious threat to public health [93].

The trend of increasing population mobility coupled with changes in land use and an increase in traffic volume on the Urip Sumoharjo-Perintis Kemerdekaan road corridor in Makassar City causes a decrease in environmental quality and air pollution. The effect of population mobility, traffic volume, and land use change on air quality pollution is shown in Table 12.

Table 12. Summary of the results of the regression coefficient significance test.

Correlated Variables		Coefficient Value	Error	t-Count	t-Table	Information
Mobility of the population to air quality pollution		0.193	0.068	2.838	1.93	Significant
Traffic volume to air quality pollution		0.134	0.050	2.680	1.93	Significant
Land use change to air quality pollution		0.402	0.095	4.232	1.93	Significant
R	R^2	db1	db2	F-hit	F-tab	
0.970	0.941	3	6	86,815	4.78	

Table 12 shows the effect of population mobility, traffic volume, and land use change on air quality pollution. Population mobility has a positive effect on air quality pollution, with a value of 0.193. Traffic volume has a positive effect on air pollution with a value of 0.134. Land use change have a positive effect on air pollution with a value of 0.402. Population mobility, traffic volume, and land use changes simultaneously have a positive effect on air pollution, with a determination coefficient of 94.1% in the corridor of the Urip Sumoharjo-Perintis Kemerdekaan Road in Makassar City.

4.2. Traffic Volume and Decreasing Environmental Quality

The pattern of transportation movement on the Urip Sumoharjo-Perintis Kemerdekaan road corridor illustrates that the complexity of land use has an impact on increasing daily traffic volume. Travel distance, car ownership, and motorcycle ownership are intermediate variables in the relationship between land use, ecosystem complexity, and distance traveled based on the use of the mode of transport [94,95]. Furthermore, an increase in traffic volume coupled with an increase in community social activities causes the flow of movement on the Urip Sumoharjo-Perintis independence road corridor to increase from time to time. This condition has an impact on increasing air pollution caused by vehicle exhaust gas and decreasing environmental quality. Air pollution refers to the number of particles released into the air that is detrimental to human health [96]. The emissions include a myriad of toxic air pollutants and carbon dioxide (CO_2), which is the most important human-produced climate-altering greenhouse gas [97]. The volume of vehicles based on the movement pattern at the traffic survey location is shown in Figure 9.

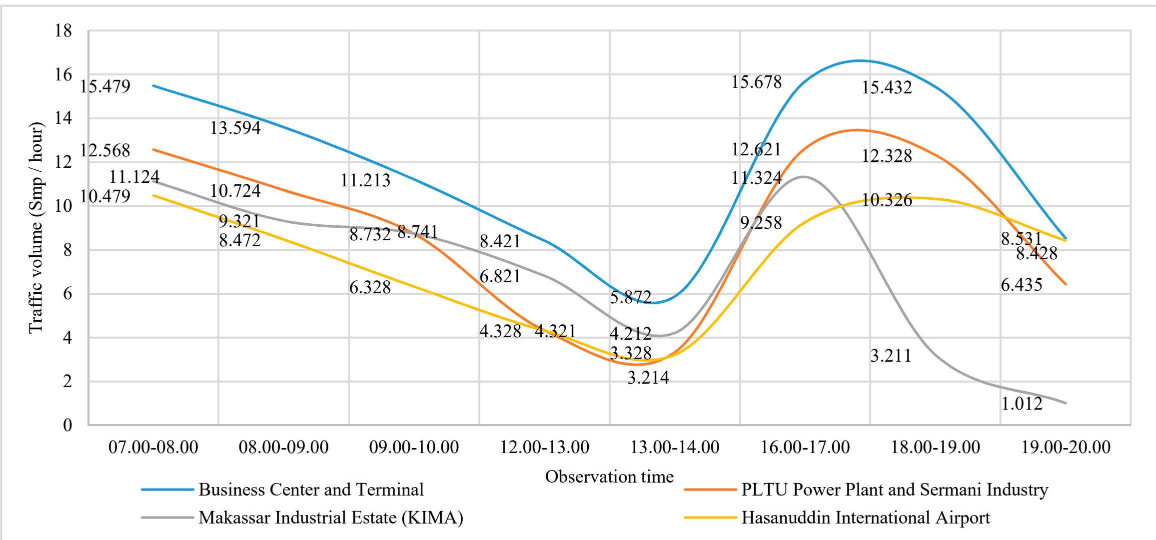

Figure 9. Traffic volume on the Urip Sumoharjo road corridor—Perintis Kemerdekaan Makassar City. Source: Survey results and primary data.

Figure 9 shows the difference in vehicle volume at the observation locations based on the type of activity that develops on the Urip Sumoharjo-Perintis Kemerdekaan Makassar City road corridor. The highest traffic volume occurs at 0.7.00–0.8.00 (first peak hour), with as many as 15,479 smp/hour at the business center and Daya terminal, 12,568 smp/hour at the PLTU and Sermani industrial power plant locations, 11,124 in the Makassar industrial area (KIMA), and 10,479 smp/hour at the location of Hasanuddin International Airport. 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 Urip Sumoharjo-Perintis Kemerdekaan road corridor. The orientation and destination of transportation movements in the morning are dominated by activities in relation to offices, education, and trade and business centers. Conversely, in the afternoon, it is dominated by movement to the area of origin. Increased traffic flow is one of the factors causing urban environmental damage and affects the sustainability of urban development [98]. Furthermore, by considering the traffic volume at the four survey locations, the assessment of the road capacity on the Urip Sumoharjo-Perintis Kemerdekaan road corridor considers (i) basic capacity (CO), (ii) effective lane width, (iii) distribution direction, (iv) side friction, and (v) population. The road capacity and degree of saturation of the Urip Sumoharjo-Perintis Kemerdekaan road corridor are shown in Figure 10.

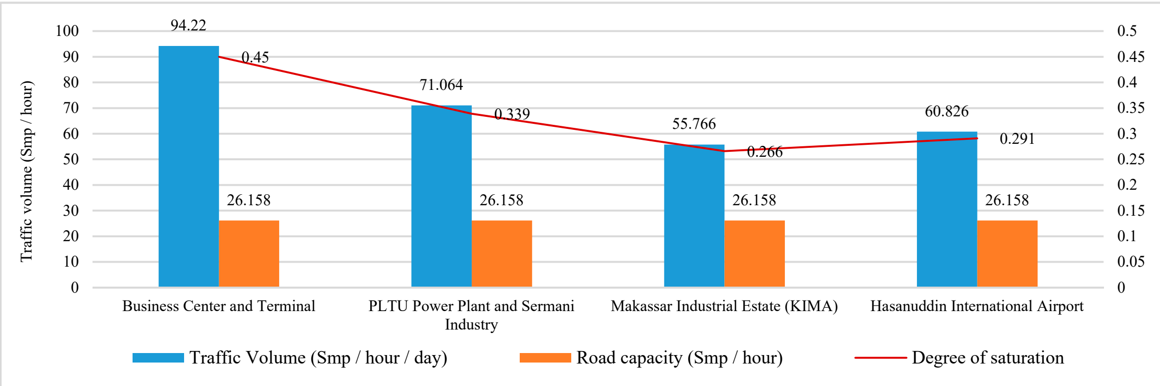

Figure 10. Traffic volume, road capacity, and degree of saturation of the road corridor Urip Sumoharjo—Perintis Kemerdekaan Makassar City. Source: Authors' elaboration.

Figure 10 shows the relationship between traffic volume, road capacity, and the degree of saturation in the Urip Sumoharjo-Perintis Kemerdekaan road corridor. The degree of saturation at the central business location and power terminals is 0.450, with a daily traffic volume of 94,220 pcu/hour. The degree of road saturation at the PLTU and Sermani industry locations is 0.339, with a daily traffic volume of 71,064 pcu/hour. The degree of road saturation at the location of the Makassar industrial area (KIMA) is 0.266, with a daily traffic volume of 55,766 pcu/hour. The degree of road saturation at the Hasanuddin International Airport location is 0.291, with a daily traffic volume of 60,826 pcu/hour. These results provide an overview of the differences and variations in daily traffic volume and the degree of road saturation. The facts found in the field show that these differences are influenced by side barriers and differences in their location characteristics (fork and road intersections). Apart from that, it is also influenced by the parking of vehicles using road bodies and the existence of non-formal economic businesses that utilize road-owned areas. Furthermore, vehicle speed, high traffic volume, and distribution of vehicle lanes have a positive effect on transportation movements in normal conditions [99]. Thus, the increase in traffic volume and the complexity of land use have a positive correlation to a decrease in environmental quality in the Urip Sumoharjo-Perintis Kemerdekaan road corridor.

Several factors have caused a decrease in environmental quality in the Urip Sumoharjo-Perintis Kemerdekaan road corridor, including (1) the complexity of land use, which causes a lack of land availability for the preparation of green open spaces, (2) excessive use of groundwater sources for the utilization of clean water needs for offices, trade, shopping centers, education facilities, industry, and services, (3) the age of the vehicle, which exceeds the usage limit required by the government, and its effect on the increase in vehicle exhaust gas, (4) community behavior related to the volume of waste generated by burning and dumping directly into the river, (5) activity waste, i.e., waste from households, offices, educational facilities, health facilities, trade and commercial facilities, industry, and other socio-economic establishments, and (6) land relocation, characterized by the use of water catchment areas for housing development needs and other socio-economic activities.

Basically, the decline in environmental quality is mainly influenced by nature and humans. The decline in environmental quality in the Urip Sumoharjo-Perintis Kemerdekaan road corridor has resulted in physical damage to the environment, urban flooding, disease transmission, and climate change. Urban flooding is the most frequent type; it is a serious obstacle to road users and impacts economic and social conditions [100–103]. Environmental quality degradation in the Urip Sumoharjo-Perintis Kemerdekaan road corridor is shown in Figure 11.

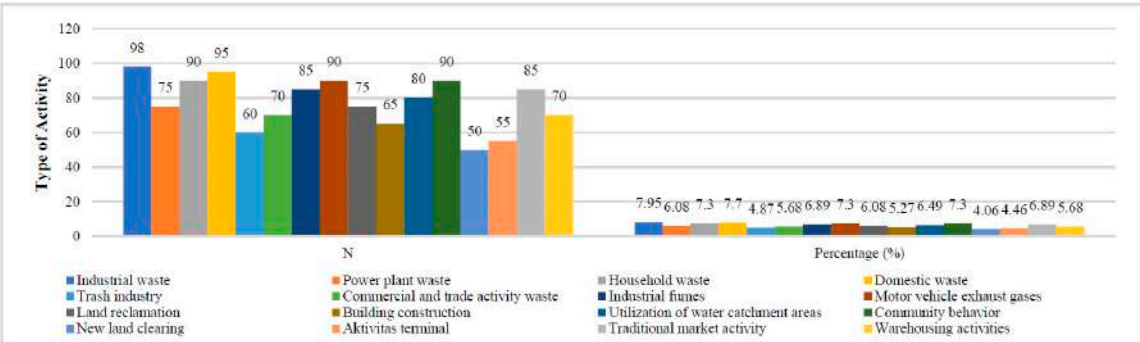

Figure 11. Decreasing environmental quality of the Urip Sumoharjo-Perintis Kemerdekaan Makassar road corridor. Source: Results of primary data analysis.

Several things that can be explained are related to the degradation of environmental quality in the corridor of the Urip Sumoharjo-Perintis Kemerdekaan Makassar City (see Figure 11), including: (1) The highest potential with a value of 7.95% comes from industrial waste and contributes to environmental degradation; (2) 7.30% comes from household waste, motor vehicle exhaust gas, and community behavior; (3) 7.70% sourced from domestic waste; and (4) 6.89% contributed by industrial activities related to air pollution and traditional market activities. This figure confirms that the complexity of land use and an increase in traffic volume are positively associated with the complexity of the ecosystem towards a decrease in environmental quality. Thus, it takes an active role from the government and society to deal with these problems. Furthermore, to ensure the sustainability of the urban environment, urban planning is an instrument used to formulate countermeasures for the government [104]. Furthermore, the direct and indirect effects of urban activity systems, transportation systems, and origin-destination movement patterns on environmental quality degradation and air pollution index are described in Figure 12 below.

The city activity system (X_1), the transportation system (X_2), and the origin and destination patterns of movement (X_3) have an effect, on environmental quality degradation. The direct effect of the city activity system on environmental quality degradation is 0.416 or 41.60%. The direct effect of the city transportation system on environmental quality degradation is 0.3481 or 34.81%. The direct effect of the origin-destination pattern of movement on environmental quality degradation is 0.1909 or 19.09%. The indirect effect of the city activity system through the transportation system is 0.2024 or 20.24%. The indirect effect of the transportation system through the city activity system is 0.2024 or 20.24%. The indirect effect of the city activity system through the origin-destination pattern of movement on environmental quality degradation is 0.1761 or 17.61%. The indirect effect of the pattern of the origin-destination movement through the city activity system on environmental quality degradation is 0.1761 or 17.61%. The indirect effect of the transportation system through the origin-destination pattern of movement is 0.1253 or 12.53%. The indirect effect of the origin-destination pattern of movement through the transportation system is 0.1253 or 12.53%. The total effect is 95.49%. Furthermore, the direct effect of environmental quality degradation on the air pollution index is 0.6609 or 66.09%. Thus, the influence of other variables on the decline in environmental quality that was not studied was 0.3391 or 33.91%.

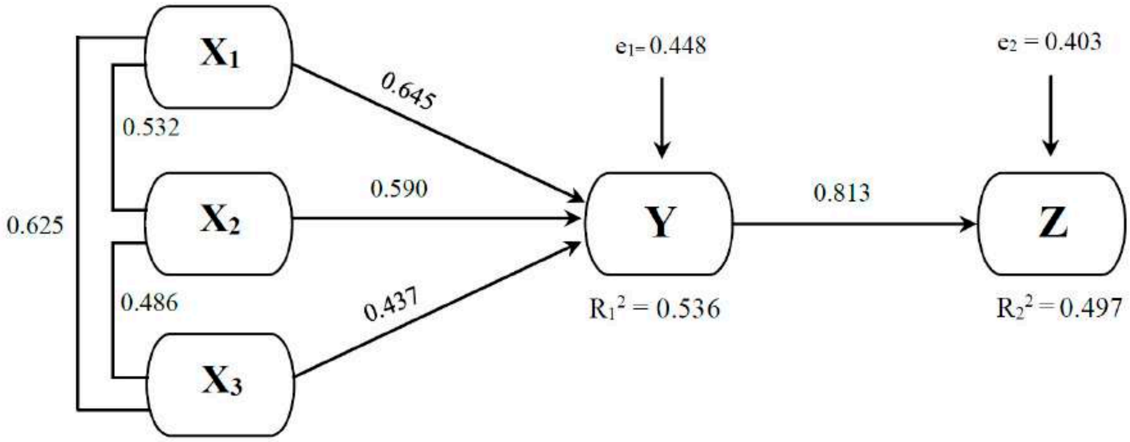

Figure 12. Relationships of the city activity system, the transportation system, and origin-destination movement patterns in relation to environmental quality degradation and the air pollution index. Source: Analysis results.

4.3. Environmental Management Strategy and Air Pollution Control

The function and role of the Urip Sumoharjo-Perintis Kemerdekaan road corridor is very strategic in encouraging the economic growth of Makassar City, leading to complex space utilization. This means that the use of space for trade and service functions is predominantly developed in the main road corridor so that it affects the level of accessibility [105]. The decline in environmental quality in the Urip Sumoharjo-Perintis Kemerdekaan road corridor is in line with the increase in air pollution, which has a positive contribution to public health conditions. The pattern of space utilization that tends to change in the corridor of the Urip Sumoharjo Perintis Kemerdekaan road is positively associated with an increase in population mobility and an increase in the flow of transportation movements from the direction of Maros Regency to the city center, industrial areas, ports, trade centers, and Hasanuddin International Airport. Thus, it is very important to control building densification and reduce private vehicle ownership towards the use of public transport [106]. Furthermore, it is very important for the development of freight transport to be aligned with efforts to save the environment in a sustainable manner [107].

Community behavior in the study area also affects environmental quality degradation—in this case, the attitudes and habits of the people who tend to throw household waste away in the local environment carelessly by burning and piling up. Indiscriminate waste disposal is recognized as an important cause of environmental pollution and is associated with health problems [108]. Protection and restoration of environmental quality is very important to involve public participation. Furthermore, in order to overcome environmental problems, it is necessary to make efforts to change people's behavior towards their environmental conditions [109].

The increasing use of motorized vehicles has an impact on increasing particles in the air due to the combustion of car engines and other motorized vehicles. The transportation sector, especially passenger transport, is a source of emissions and affects environmental conditions [110]. The direct impact on public health conditions is characterized by lung disease, eye irritation, and respiratory tract infections. Particulate matter emissions and industrial fumes have a direct impact on human health and other environmental problems [111]. Thus, it is necessary to support the role of government in making strategic decisions in relation to pollution control programs and environmental restoration in the framework of realizing environmental health. Thus, efforts are needed to harmonize sustainable development and strategic management and its implementation in the field [112]. In addition, the role of the community is needed in maintaining environmental stability, leading to the realization of a healthy and sustainable environment. Thus, public participation of environmental governance is likely to be an irreversible trend [113]. To corroborate the findings of this study, strategic steps are needed to maintain environmental sustainability. Environmental management strategies and air pollution control in the Urip Sumoharjo-Perintis Kemerdekaan road corridor are detailed in Table 12.

Table 13 shows some of the strategies needed in environmental management and air pollution control in the Urip Sumoharjo-Perintis Kemerdekaan Makassar City road corridor. Furthermore, to implement this strategy will require government policy support in terms of increasing traffic safety in a comprehensive and integrated manner from various aspects, namely prevention, guidance, law enforcement, handling of accident impacts, handling accident-prone areas, environmental information systems, traffic feasibility, availability facilities, and applications of air quality standards. Thus, driving safety on the highway is an effort to maintain the safety of road users [114,115].

Table 13. The strategy of environmental management and air pollution control of the road corridor of Urip Sumoharjo-Perintis Kemerdekaan Makassar City.

Internal	Strength	Weakness
External	• Primary arterial road function • Connecting the activity centers of Makassar City • Covered by all city movements • The road accessibility is quite high • Mixed use land	• Inadequate road capacity • Use of road bodies as a means of parking and traffic jams • The vehicle density is quite high and there is potential for air pollution • The side barriers are quite complex • Utilization of water catchment areas
Opportunity	Strategy (SO)	Strategy (WO)
• Funding support from the central government • Sufficient road infrastructure support • Financial support from the private sector • Community participation • Management of space utilization permits	• Optimizing the use of funds for transportation management • Effectiveness of road infrastructure utilization and transport movement system regulation • Use and utilization of mass transportation for passenger transportation • Limiting spatial use and land elevation adjustments • Optimizing community participation in environmental management	• Increase the capacity of road bodies and transport management arrangements • Regulating the freight transport system and law enforcement • Control air pollution through checking vehicle exhaust gases regularly • Arrangement of road ownership areas and road supervision areas • Prevention and control of utilization of water catchment areas through tightening permits
Threats	Strategy (WO)	Strategy (WT)
• Limited funds • Road user behavior • The pollution load is quite high • High socio-economic activity • Global climate change	• Optimizing the role of the private sector in managing the transportation system • Optimizing community participation in transportation management • Limiting the addition of economic activity functions and zoning arrangements • Environmental information system-based pollution control • Adaptation to global climate change based on environmental management of transportation	• Utilization of private funds in transportation management • Transportation management by applying an odd-even system • Improve traffic safety through law enforcement • Improve road transport traffic infrastructure conditions to minimize material loss and time value • Optimization of intermodal integration and efficiency in supporting human mobility, distribution of goods and services.

Source: Analysis results.

Furthermore, to address the increase in traffic volume and increase in air pollution in the Urip Sumoharjo-Perintis Kemerdekaan road corridor, simultaneous traffic management and air quality monitoring are required, including (1) capacity management, in the form of road widening, intersections not level with flyovers and underpasses, geometric intersection improvements, and off-street parking spaces; (2) priority management, in the form of public transport lanes, special lanes for non-motorized vehicles, special lanes for goods transportation, arrangements for pedestrians, zebra crossings, pelican crossings, pedestrian bridges, queue management, ticket management, bus traffic arrangement, and city transportation; and (3) traffic demand management, namely the application of the concept of vehicle occupancy rates, restrictions on vehicle years, restrictions on vehicle ownership, restrictions on the use of road bodies for parking, and application of progressive taxes. Road traffic accidents are one of the most critical problems for human life and can be decreased significantly; identifying the causes of traffic accidents is the most critical procedure in adopting precautionary measures to reduce their severity and quantity [116,117].

5. Discussion

5.1. Environmental Management and Air Pollution Control Solutions

The increase in the development activities of Makassar City and the increase in population mobility, which tends to increase usage of the Urip Sumoharjo-Perintis Kemerdekaan road corridor, have contributed positively to the decline in environmental quality and its impact on air pollution. Thus, solutions are necessary to overcome environmental quality degradation and air quality pollution. The use of two-wheeled vehicles and private cars needs to be reduced. The use of public transportation is aimed at being safe, comfortable, and efficient. Green infrastructure—in this case, the preparation of green open spaces through the planting of anti-pollutant vegetation along the road's dividing line (a road median with a width of 1–2 m) and in the supervision area—is needed. Changes in behavior and participation in all environmental activities are needed to maintain the quality of settlement environments. Green building implementation needs to be applied to buildings and in yards in residential buildings. Vehicle emission tests need to be carried out regularly through strict supervision and control. Electricity consumption needs to be reduced in housing, offices, and commercial buildings. Used materials need to be recycled into new materials with the aim of preventing waste, reducing the use of new raw materials, reducing energy use, reducing pollution, degrading land, and emitting greenhouse gases. Efforts are needed to develop and apply new knowledge, which leads to innovative, technological, and sustainable processes, products, and services [118]. Further, efforts are needed to promote environmentally friendly transportation designs, reduce greenhouse gas emissions, enable a safer supply of raw materials, and promote competitiveness and technological innovation and job creation [119,120].

The role of government in the framework of preventing and handling air pollution in the Urip Sumoharjo-Perintis Kemerdekaan road corridor requires support in the formulation of strategic policies. The steps required include the following: (1) The support of laws and regulations on air pollution control by referring to, to name some, ambient air quality standard regulations according to WHO standards, regulations on the use of vehicle fuel, regulations on motor vehicle emission testing, and regulations to reduce air pollution emissions from industry; (2) better cross-sectoral coordination with academics and professional organizations to address air pollution problems across all sectors, using studies to determine the sources of air pollution in urban areas (emissions inventory) and to assess the health impact of air pollution on communities and efforts; (3) taking steps to reduce air pollution such as promoting and implementing emission tests for motor vehicles entering the Urip Sumoharjo-Perintis Kemerdekaan road corridor, especially public vehicles or freight vehicles, and monitoring air pollution emissions and administering strict punishments to industries that are not environmentally friendly; (4) promoting alternative power plants, such as wind power, wave power, and solar power, to reduce air pollution emissions from power plants; (5) supporting mass transportation facilities that are safe, comfortable, inexpensive, environmentally friendly, and easily accessible; (6) preparing parking lots adjacent to public transportation facilities that are feasible, safe, affordable, and able to accommodate needs for transportation for economic activities and other social activities; (7) campaigning for the use of electric vehicles (cars and electric motorbikes) and increasing the number of public vehicles with electric power; (8) increased tree planting and green areas; (9) maximizing air pollution monitoring and early warnings in the community by increasing the number of monitoring points/measuring instruments for air quality and by providing information that is easily accessible to the public; (10) regularly providing information to the public about unhealthy air quality conditions and the anticipatory steps that can be taken by the public in various media (print, electronic, and social media); and (11) preparing a health service system to serve people affected by air pollution. Although no firm evidence of an association between air pollution and overall mental health has been found, the results show significant evidence of a positive relationship between air pollution and depression [121,122].

Solutions for handling environmental quality degradation and air pollution control in the corridor of the Urip Sumoharjo-Perintis Kemerdekaan of Makassar City are contextualized on several matters, including: (1) Tightening the licensing process in relation to utilization; (2) building public awareness to participate in environmental management; (3) implementing incentives for activities that have the potential to pollute the environment through tightening supervision and implementing progressive taxes on the pollution caused; (4) requiring public open space for every component of socio-economic activities, including housing, offices, commercial buildings, and other activities, through planting shade trees capable of absorbing noise, breaking down dust particles, and motor vehicle fumes, which are supported by regional regulations of Makassar City; (5) carrying out efforts to protect changes in land cover along river basins followed by the implementation of a conservation program; (6) establishing a Buffer Zone to maintain ecological balance and become the lungs of the city, so that CO toxins and CO_2 emissions from motorized vehicle combustion and industrial fumes can be absorbed in the buffer zone and with the photosynthetic process converted into oxygen necessary for life; and (7) utilizing the road median to be used as a green open space to absorb levels of carbon dioxide (CO_2), increase oxygen, reduce the temperature with the shade and coolness of plants, become a water catchment area, and reduce noise. In its implementation, the seven basic principles require the participation of stakeholders and active community participation.

Furthermore, the cycle of managing and controlling air quality pollution in the Urip Sumoharjo-Perintis Kemerdekaan of Makassar City road corridor requires strategic steps, including: (1) Monitoring ambient air quality (environment), through an evaluation process, air quality analysis, and its impact based on pollutant levels the highest; (2) establishing air quality pollution limits based on the National Ambient Air Quality Standards (NAAQS); (3) formulating strategic planning related to air quality pollution control; and (4) building cooperation between the government, the private sector, and the community for the implementation and control of air pollution in the Urip Sumoharjo-Perintis Kemerdekaan road corridor. These four things are implemented through various actions, namely (i) outreach to the community, (ii) preventive action by reducing emissions, (iii) recycling, (iv) redesign, (v) implementation of Resource Efficient and Cleaner Production (clean production targets energy, water, and raw materials), and (vi) management and of pipe (waste). These six things will require a review of government policies, namely (a) establishing emission quality standards, (b) formulating and establishing new policies, and (c) a strategy and implementation of air pollution control based on the air quality management cycle set by the central government and the Makassar City government.

5.2. Sustainability of Environmental Management and Transportation Systems

The sustainable environmental management in the corridor of the Urip Sumoharjo-Perintis Kemerdekaan Makassar City cannot be separated from efforts to manage and conserve the environment in general. The orientation of sustainable development covers economic, social, and environmental aspects. Furthermore, environmental management employing the polluter-pay principle is needed. This would mean that the environmental management mechanism is borne by the company, which has the potential to generate pollutants and involve the community. As an essential stakeholder of environmental resources, the public has become a third force in promoting environmental governance, together with local governments and polluting enterprises [123].

Furthermore, in order to overcome the problem of environmental quality degradation and air pollution load, three main criteria need to be considered in government decision making: (1) Optimizing the utilization of natural resources and the environment through zoning arrangements for spatial use in the Urip Sumoharjo-Perintis road corridor; (2) reducing pollution and other environmental impacts through green infrastructure and green buildings; and (3) increasing the use of renewable resources. These three elements will require integration and coordination that is cross-sectoral, integrating natural resources, human resources, and artificial resources. Furthermore, optimizing the coordinated use of space in an effective manner is positively associated with environmental sustainability. The urban ecological space functionally has significant differentiating characteristics in terms of the layout of socio-economic activities [124].

The implementation of a sustainable transportation system in the Urip Sumoharjo-Perintis Kemerdekaan road corridor is oriented to contribute positively to the environmental, social, and economic sustainability of the community. This means that a sustainable transportation system entails social, economic, environmental, and climate impacts. Its implementation requires easy access for the community for the interests of business, education, the transportation of goods and services, and the minimization of environmental impacts and traffic jams. Thus, the implementation of a sustainable and environmentally friendly transportation system in the Urip Sumoharjo-Perintis Kemerdekaan road corridor will require (1) the development of access points such that security is more maintained, is humane, does not pollute the environment, and provides intergenerational justice; (2) efficient operation, in that it provides a choice of transportation modes and supports the movement of the socio-economic aspects of society; and (3) limit emissions, minimizes the use of renewable natural resources, and minimizes the use of land that can pollute the environment. The triple bottom line principle includes resource conservation, cost efficiency, and design for human adaptation [125].

The implementation of a sustainable transportation system must be oriented towards (a) increasing accessibility through transportation network system planning and the integration of transport modes, (b) providing affordable transportation for all levels of society and upholding healthy business competition, the shared use of space, the fair use of infrastructure, and transparency in policy making, and (c) a negative impact reduction through the use of environmentally friendly energy, environmentally friendly transportation facilities, and planning that prioritizes the safety of transportation users. The transportation sector is very important to develop towards the sustainability of the system of movement of goods and people in relation to the environmental impacts that are caused [126,127]. Furthermore, urban transportation options are very important to be oriented towards the use of mass transportation in order, to reduce the environmental impact caused [128]. The scheme for the sustainability of environmental management and the transportation system in the Urip Sumoharjo-Perintis Kemerdekaan road corridor is shown in Figure 13.

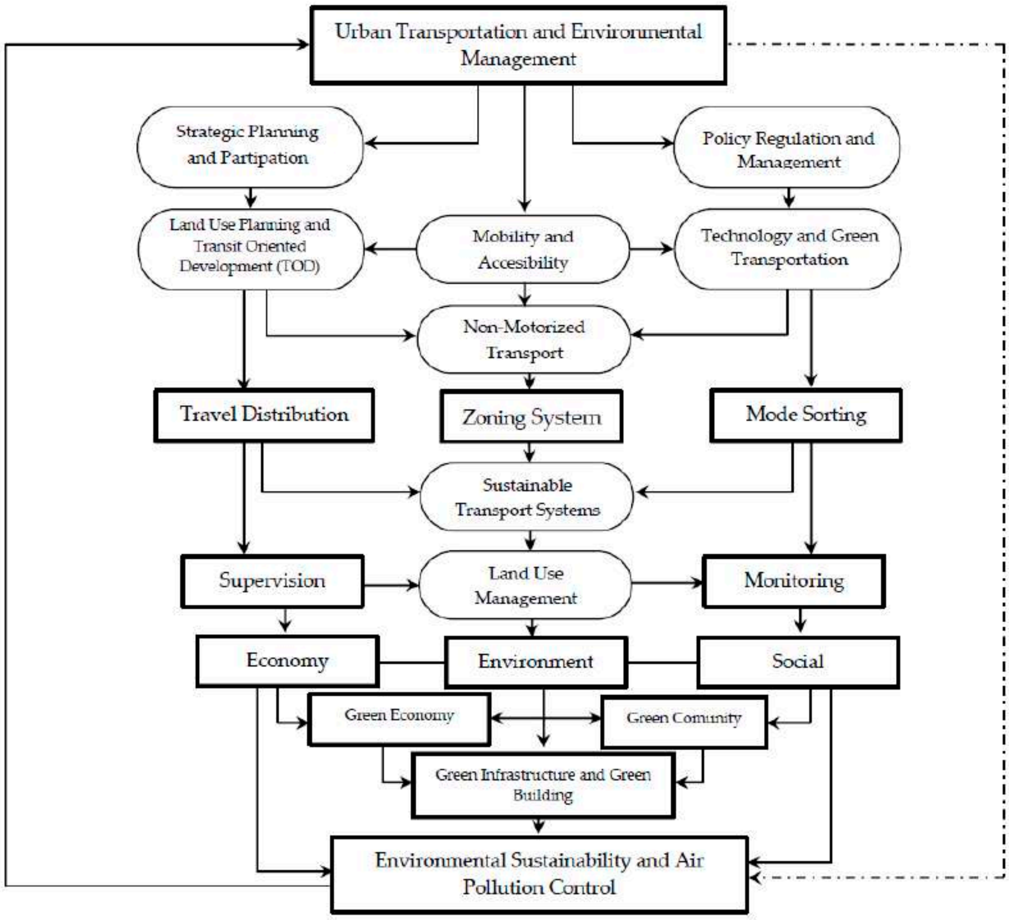

Figure 13. The sustainability of environmental management and transportation systems in the corridor of the Urip Sumoharjo-Perintis Kemerdekaan, Makassar City. Source: Author elaborator.

6. Conclusions

The trend in the development of the dominant socio-economic activities developed in the corridor of the Urip Sumoharjo-Perintis Kemerdekaan Makassar City is caused by weak control over space utilization and the ease of licensing issued by the government. The complexity of space utilization has an impact on environmental quality degradation. In addition, the mobility of the population, which is in line with the complexity of land use in the Urip Sumoharjo-Perintis Kemerdekaan road corridor, has an impact on increasing traffic volume. The mobility of the population is in line with the high volume of traffic that is not proportional to the capacity of the road, which has an impact on traffic jams, traffic accidents, and air quality pollution. The air quality pollutant index in the Urip Sumoharjo-Perintis Kemerdekaan road corridor is divided into three categories based on the allocation of developing land uses: (1) Business centers, power terminals, PLTU power plants, and Sermani industry are categorized as polluted; (2) the Makassar Industrial Area (KIMA) is categorized as highly polluted, and (3) the Hasanuddin International Airport Area is categorized as non-polluted. The complexity of land use and the high volume of traffic, coupled with an increase in community social activities, has an impact on increasing air pollution produced by vehicle exhaust gases, which leads to a decrease in environmental quality. Thus, population mobility, traffic volume, and land use changes simultaneously have a positive effect on air pollution in the Urip Sumoharjo-Perintis Kemerdekaan corridor in Makassar City. Thus, a serious handling is required in terms of regulation and management of the transportation system and supported by community participation.

The complexity of land use contributes positively to the complexity of the ecosystem towards a decrease in environmental quality, due to the role of the Urip Sumoharjo-Perintis Kemerdekaan road corridor in addition to connecting from the city center to the urban area of Makassar City, it also functions to connect the Metropolitan Mamminasata urban functional area. Environmental quality degradation in the Urip Sumoharjo-Perintis Kemerdekaan road corridor is influenced by several factors: (i) Complexity of land use, (ii) excessive use of groundwater sources, (iii) vehicle life that exceeds usage limits, (iv) incineration of garbage and disposal direct to rivers, (v) waste from city activities, and (vi) land relocation, which is indicated by the use of water catchment areas for housing development needs and other socio-economic activities. These factors contribute positively to the complexity of the ecosystem and environmental pollution (water, soil, and air). The results path analysis confirm that the city activity system, transportation system, and movement patterns based on origin-destination have a direct effect on the degradation of environmental quality and air pollution index. Thus, cooperation between various parties, namely the government, the private sector, and the community is needed in overcoming environmental quality degradation in the Urip Sumoharjo-Perintis Kemerdekaan City Makassar corridor. Directions for handling that can be carried out are, among others: (1) Zoning arrangements for space utilization; (2) implementation of incentive and disincentive policies; (3) application of progressive tax against spatial planning violations; and (4) application of air quality standards through checking gas emissions from vehicles operating regularly.

Air pollution control strategies and environmental management sustainability require the support of government policies in terms of improving traffic safety in a comprehensive and integrated manner for various aspects, namely prevention, guidance, law enforcement, handling of accident impacts, handling accident-prone areas, environmental information systems, feasibility of traffic facilities, traffic, and application of air quality standards. Thus, the necessary solutions to overcome environmental quality degradation and air quality pollution include: (i) Use of public transportation; (ii) green infrastructure application; (iii) changing community behavior and participating in all environmental management activities; (iv) green building application; (v) regularly test vehicle emissions through close supervision and control; (vi) save energy; and (vii) use of recycled products.

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