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Air Quality Improvement Strategy in One of Jakarta's Transit-Oriented Development Areas

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ABSTRAK

Latar belakang: Polusi udara masih menjadi tantangan yang terus berlanjut di Jakarta, meskipun berbagai intervensi dan kebijakan telah dilakukan oleh pemerintah, termasuk penerapan kawasan Transit Oriented Development (TOD). Secara ideal, kawasan TOD seharusnya memberikan dampak positif terhadap lingkungan, khususnya melalui peningkatan kualitas udara dengan cara mengurangi penggunaan kendaraan pribadi, yang merupakan salah satu sumber utama polusi udara di kota ini. Penelitian ini bertujuan untuk merumuskan strategi peningkatan kualitas udara di kawasan TOD Dukuh Atas.

Metode: Pengumpulan data dilakukan melalui observasi langsung serta wawancara dengan para ahli yang memiliki pemahaman mendalam mengenai kebijakan peningkatan kualitas udara. Metodologi penelitian mencakup penyebaran kuesioner kepada masyarakat, wawancara dengan informan kunci, dan analisis SWOT (*Strengths, Weaknesses, Opportunities, Threats*).

Hasil: Hasil analisis SWOT menunjukkan bahwa strategi diversifikasi—dengan memanfaatkan kekuatan untuk mengurangi risiko yang ditimbulkan oleh ancaman—merupakan pendekatan yang paling efektif untuk peningkatan kualitas udara. Dari empat alternatif strategi yang dirumuskan, pendekatan S-T (Strength-Threat) diidentifikasi sebagai prioritas utama, diikuti oleh strategi W-O (Weakness-Opportunity), S-O (Strength-Opportunity), dan W-T (Weakness-Threat).

Simpulan: Strategi yang direkomendasikan meliputi perluasan area dengan akses terbatas untuk kendaraan bermotor di zona transit serta penetapannya sebagai Kawasan Emisi Rendah (Low Emission Zone/LEZ), peningkatan kapasitas dan jumlah moda transportasi umum, pengembangan stasiun pemantauan kualitas udara di kawasan TOD, serta penerapan solusi ruang hijau vertikal.

Kata kunci: Polusi Udara; Transit Oriented Development; Strategi Peningkatan Kualitas Udara

ABSTRACT

Background: *Air pollution remains a persistent challenge in Jakarta, despite various government interventions and policies, including the implementation of Transit Oriented Development (TOD) areas. Ideally, Transit Oriented Development areas should positively impact the environment, particularly by improving air quality through reducing private vehicle usage, which is a primary source of air pollution in the city. This study aims to formulate strategies for enhancing air quality within the Dukuh Atas Transit Oriented Development area.*

Method: *Data were collected through direct observation, interviews with experts possessing in-depth knowledge of air quality improvement policies. The research methodology involved community questionnaires, key informant interviews, and a SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis.*
Result: *The results of the SWOT analysis indicate that a diversification strategy-leveraging strengths to mitigate risks posed by threats-is most effective for air quality improvement. Among the four alternative strategies formulated, the S-T (Strength-Threat) approach was identified as the top priority, followed by W-O (Weakness-Opportunity), S-O (Strength-Opportunity), and W-T (Weakness-Threat) strategies.*
Conclusion: *The recommended strategies include expanding the area of restricted access for motorized vehicles within the transit zone and designating it as a Low Emission Zone (LEZ), increasing the capacity and number of public transportation options, developing air quality monitoring stations in the Transit Oriented Development area, and implementing vertical green space solutions.*

Keywords: Air Pollution; Transit Oriented Development; Air Quality Improvement Strategy

INTRODUCTION

Jakarta as the capital city of the Republic of Indonesia is the city with the largest population in Indonesia, which is 10.748.230 people in 2022.[1] The increase in population due to urbanization will be followed by an increase in transportation needs for mobility, which is one of the main factors of air pollution.[2] According to Air Quality Index (IQAir) data in 2023, Jakarta was ranked first several times in the list of countries with the highest air pollution levels in the world. Air pollution can cause human health problems, especially the respiratory tract and also has a negative impact on the environment.[3] Exhaust emissions from motor vehicles contribute 70-80% of total air pollution, while those from industry only contribute 20-30%.[4] Approximately, 60% of Jakarta residents suffer from respiratory problems caused by poor air quality in Jakarta.[5]

A significant increase in the number of motorized vehicles has the potential to drive economic growth, but it can also create environmental problems such as noise, congestion, and air pollution[6]. Therefore, transportation plays an important role in strategic issues such as economy, climate change, and health because it is the source of air pollution in cities[7] Air pollution triggers negative impacts on public health, the environment, and economic issues, requiring decision makers to control pollution at the source through implemented policies.[8] In terms of health, air pollution can cause direct harm that may occur suddenly, acutely, chronically, subclinically, and with or without symptoms.[9] Air pollution from transportation was responsible for 3,5 million premature deaths in 2017, primarily linked to respiratory infections, diabetes, cardiovascular diseases, lung infections, obstructive disorders, and cancer.[10] In accordance with the plan to unify transportation and land use planning, one of the policies being implemented by the DKI Jakarta Provincial Government is the development of Transit-Oriented Development (TOD) areas to reduce dependence on private vehicles.[9]

The TOD approach is particularly relevant given the high levels of congestion and air pollution in Jakarta.[10] Based on research by,[11] the implementation of TOD in the Jakarta metropolitan area is still in its early stages. The advantages of Transit-Oriented Development extend beyond promoting public transit usage and decreasing reliance on automobiles; they also encompass stimulating regional economic growth, enhancing environmental quality, and improving community amenities.[12] According to[13] the implementation of TOD in major world cities has an influence in attracting and increasing many passengers to use public transportation.[14] But in reality, based on data from the DKI Jakarta Provincial Government in 2019, 78,3% of Jakarta residents still tend to use private vehicles rather than public transportation.

According to Governor Regulation No. 15 of 2020, PT Mass Rapid Transit (MRT) Jakarta was appointed to oversee Transit-Oriented Development corridors throughout Jakarta. The implementation of transit-oriented districts in Jakarta began with the initial development of the MRT system in 2015. From the beginning of construction on the Lebak Bulus-Dukuh Atas line, PT MRT Jakarta has integrated the TOD concept into its station designs.[10] The Dukuh Atas district was recognized for its relatively comprehensive urban planning as a Transit-Oriented Development zone, featuring well-designed walkways, cycling infrastructure, public transportation access, diverse land utilization, and adequate green spaces.[15] Although several TOD areas have been implemented in Jakarta, air pollution still continues to occur. Yet there are many successful countries that Indonesia can emulate in implementing TOD in global cities such as Stockholm, Copenhagen, Tokyo, Singapore, and Hong Kong.[12,16]

Several previous studies discussing TOD (Transit-Oriented Development) areas in Jakarta have primarily focused on evaluating the implementation of TOD in Jakarta,[17–20] measuring accessibility and land use indices,[21,22] pedestrian accessibility[23,24] as well as evaluating characteristics and concepts,[9,15,25,26] and the accessibility and affordability of TOD areas.[27,28] However, to date, there have been no previous studies that specifically address strategies for improving air quality in Jakarta's TOD areas. Therefore, this research aims to strategize what can be done to improve air quality in Transit-Oriented Areas. With these strategies, it is expected that the implementation of

TOD areas can have a significant influence in overcoming air pollution problems in big cities, especially Jakarta.

MATERIALS AND METHODS

This study employs quantitative methods, utilizing both primary and secondary data sources to analyze air pollution control strategies. Primary data were collected through direct field observations, interviews, and expert questionnaires, while secondary data were obtained from previous research and documents related to air pollution control policies and planning. Expert sampling was conducted using a purposive sampling technique, targeting stakeholders with comprehensive knowledge of government policy, regulatory frameworks, and the implementation of air quality improvement strategies. The stakeholders involved include representatives from PT MRT, the Jakarta Environment Agency, and the Jakarta Transportation Agency. The assessment and weighting of SWOT factors were performed through expert questionnaires, with five respondents comprising representatives from PT MRT, the Jakarta Environment Agency, the Jakarta Transportation Agency, academia, and non-governmental organizations (NGOs). The five SWOT respondents in this study were purposively selected to represent the principal stakeholders in air pollution control within the Dukuh Atas Transit-Oriented Development (TOD) area. PT MRT Jakarta, as the TOD area manager, plays a pivotal role in the planning and development of integrated public transportation systems aimed at promoting a modal shift toward low-emission mass transit. The Jakarta Environment Agency is responsible for the systematic monitoring of ambient air quality and the enforcement of environmental regulations, while the Jakarta Transportation Agency holds a strategic mandate in mitigating transportation-related emissions through vehicle operational regulations, traffic restriction measures, and the formulation of sustainable transportation policies. Academia contributes scientific analysis and evidence-based evaluation, whereas non-governmental organizations (NGOs) provide community perspectives and engage in policy advocacy. The selection of these respondents was guided by their subject-matter expertise, strategic institutional roles, and direct involvement in policy formulation and implementation, ensuring that, despite the limited sample size, the data collected are both in-depth and representative for reliable strategic analysis. Although the total number of respondents was five, this composition was considered sufficient for the research objective because the study applied an expert judgment approach, which emphasizes the quality and depth of knowledge rather than the size of the sample. This approach is common in SWOT-based strategic analyses, where the primary goal is to obtain informed and authoritative assessments of internal and external factors rather than to generalize findings to a broader population. The collected data were systematically analyzed through data reduction, presentation, and conclusion drawing. The findings of this research are expected to provide valuable insights for the development of effective air pollution control policies and strategies in urban environments.

Data were analyzed using the SWOT method to identify internal and external factors influencing air quality in transit-oriented development (TOD) areas, and to formulate strategies to mitigate weaknesses and threats by leveraging existing strengths and opportunities. The analysis commenced with the identification of internal factors (Internal Factor Analysis Summary, IFAS), encompassing both strengths and weaknesses, as well as external factors (External Factor Analysis Summary, EFAS), which include opportunities and threats, based on the collected data.

Experts selected based on particular requirements responded to surveys to assign importance values to individual elements. Each element's relevance was rated on a 1-4 scale, spanning from "extremely insignificant" to "extremely significant" for development purposes. After establishing the weighted values, elements were prioritized, and final ratings were determined by calculating mean weights using Microsoft Excel's computational capabilities. This score represents the degree to which each factor influences efforts to improve air quality in TOD areas. The total score was obtained by multiplying the weights by the rankings, and the results were subsequently organized into a matrix. Air quality enhancement approaches were subsequently organized into four distinct classifications: leveraging internal strengths to exploit external possibilities (SO), addressing organizational weaknesses while pursuing available opportunities (WO), utilizing existing strengths to counter external challenges (ST), and minimizing internal vulnerabilities while avoiding external risks (WT) which were subsequently mapped into the SWOT analysis quadrants. The determination of strategic coordinates was based on the results of the score calculations.

This study will focus on the Dukuh Atas TOD area, which is one of the twelve stations designated as TOD zones in Jakarta according to the Jakarta Provincial Medium-Term Development Plan (RPJMD) 2017–2022. This area has been established as a pilot project and serves as a premium transit station accommodating five modes of transportation: Jakarta Mass Rapid Transit (MRT), Transjakarta Bus Rapid Transit (BRT), airport rail link, commuter rail, and Light Rapid Transit (LRT). The Dukuh Atas TOD area is the first TOD zone developed in Jakarta and serves as a model for transit-oriented development in the Greater Jakarta area (Jabodetabek) [25]. The Dukuh Atas TOD area is located in both Central Jakarta and South Jakarta, encompassing three sub-districts: Tanah Abang, Menteng, and Kuningan. The total area covers 141.5 hectares, which includes four urban villages:

Setiabudi (21.6 ha), Kebon Melati (48.3 ha), Menteng (45.1 ha), and Karet Tengsin (26.4 ha).[29] The location of the research map can be seen in the following figure.

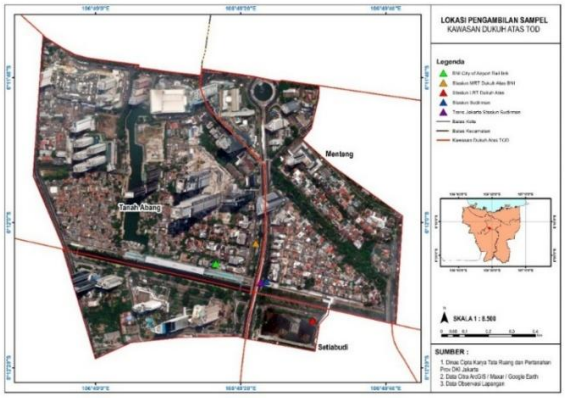

Fig. 1. Research location in Dukuh Atas TOD area, Jakarta, Indonesia

RESULTS AND DISCUSSION

The SWOT analysis is focused on internal and external environmental factors that directly affect air pollution in the TOD Dukuh Atas Area. The results of the analysis will serve as the basis for formulating alternative strategies to improve air quality in the Dukuh Atas TOD Area. Internal factors (IFAS) refer to internal elements that influence efforts to enhance air quality, which consist of Strengths and Weaknesses. Strengths are the strengths or advantages possessed by the location of the Dukuh Atas TOD Area. Weaknesses are negative factors that can contribute to air pollution in the Dukuh Atas TOD Area.

The strength factor with the highest weight is the closure of motorized vehicle access on several roads. This factor gets the highest weight because the more limited motorized vehicles passing through the TOD area, the less emissions will be. The strength factor with the lowest weight is the evaluation and monitoring of management carried out regularly. This factor received the lowest weight because there is still a need to improve evaluation and monitoring, especially related to air quality in the Dukuh Atas TOD area. The weakness factor with the highest weight is the high activity of private vehicles around the area and the lack of real-time air quality monitoring facilities in the Dukuh Atas TOD area. The results of the identification of internal strategic factors can be seen in Table 1.

Table 1 Analysis of Internal Factors

Internal Factors (IFAS)			
	Weight	Rating	Total
Strengths			
Dukuh Atas TOD area has a strategic location that supports high community activity.	0.10	4.00	0.41
Integrated infrastructure that supports connectivity and mobility efficiency in Dukuh Atas TOD area.	0.09	3.60	0.33
The commitment of the DKI Jakarta government through the Air Pollution Control Strategy (SPPU).	0.09	3.60	0.32
Closure of motorized access on several roads.	0.09	3.40	0.74
Community involvement in area development.	0.10	3.80	0.36
Evaluation and monitoring of management is conducted regularly.	0.09	3.40	0.29
Total			2.01
Weaknesses			
There is no specific policy related to air pollution control in the development of TOD areas.	0.09	3.40	0.29
High activity of private vehicles around the area.	0.10	3.80	0.37
Lack of real-time air quality monitoring facilities in TOD areas.	0.10	3.80	0.37
Land limitation in Dukuh Atas TOD Area.	0.08	3.20	0.26
Funding constraints are still focused on infrastructure, with no specific allocation for air quality improvement.	0.09	3.60	0.33
Total			1.61
Total IFAS			3.62

Based on the IFAS analysis results, a total strength score of 2.01 and a weakness score of 1.61 were obtained, resulting in a total IFAS score of 3.62. This score reflects that internally, the Dukuh Atas TOD area is in a relatively strong position to support strategies to improve air quality. Factors such as a strategic location that supports community activities, integrated infrastructure that facilitates connectivity, and the commitment of the DKI Jakarta Provincial Government through its air pollution control strategy are important assets in the development of the area. However, there are still significant weaknesses, including the absence of specific policies related to air pollution control in the TOD area, high levels of private vehicle activity, limited real-time air quality monitoring, and limited land and funding that is still focused on infrastructure. A comparison between strengths (2.01) and weaknesses (1.61) shows that the Dukuh Atas TOD area has internal strengths that are more dominant than its weaknesses in the context of air quality management.

External factors that influence air quality in the Dukuh Atas TOD (Transit-Oriented Development) Area are categorized as External Strategic Factors (EFAS), consisting of Opportunities and Threats. Opportunities refer to favorable external conditions that can be leveraged to improve air quality in the TOD area. Conversely, Threats are external conditions that may pose risks or challenges to air quality in the area. Based on the EFAS matrix, the highest-rated strategic opportunity is the potential for collaboration with the private sector and community groups in developing air quality monitoring technologies, with a score of 0.46. The lowest-rated opportunity is the advancement of

digital media that facilitates access to public information and education, which scored 0.37. The most significant threat to improving air quality in the Dukuh Atas TOD area is the persistently high level of air pollution in Jakarta, which can adversely affect air quality within the TOD zone, with a score of 0.46. The lowest-rated threat is the negative economic impact of air pollution. The detailed identification of external strategic factors is presented in Table 2.

The results of the EFAS analysis show that the total score for opportunities (1.66) is slightly lower than the total score for threats (1.85), resulting in an overall EFAS score of 3.51. This indicates that the Dukuh Atas TOD area faces a relatively challenging external environment. This area has considerable opportunities, particularly through collaboration with the private sector for technology development, public support for stricter environmental policies, the role of digital media in disseminating information, and increasing awareness of the importance of public transportation in reducing air pollution. However, external threats are more dominant, including the high level of air pollution in Jakarta, the rapid increase in motor vehicle use due to urbanization, potential policy shifts that may hinder pollution control efforts, and geographical as well as climatic conditions that can exacerbate pollution concentrations.

Different approaches are formulated by integrating factors from both within and outside the organization, creating four distinct strategic options: leveraging strengths to capitalize on opportunities (S-O strategy), addressing weaknesses to pursue opportunities (W-O strategy), using strengths to mitigate threats (S-T strategy), and minimizing weaknesses while avoiding threats (W-T strategy). These four strategic alternatives are outlined in Table 3.

According to the weighting results, the overall score for Strengths exceeds that of Weaknesses within the internal factors, whereas the total score for Opportunities is lower than that of Threats in the external factors. Therefore, based on the coordinate value calculation, the air quality improvement strategy falls into Quadrant II, which is a diversification strategy with coordinate points (0.4; -0.19). The strategy in Quadrant II is the S-T strategy, which utilizes strengths to address threats. The results of the SWOT analysis quadrant can be seen in Figure 2, and the priority order of strategies can be found in Table 4 below.

Table 2 Analysis of External Factors

External Factors (EFAS)			
	Weight	Rating	Total
Opportunities			
Potential collaboration with the private sector and communities for air quality monitoring technology development.	0.12	3.80	0.46
Community support for new, stricter policies/regulations to improve air quality in transit areas.	0.11	3.60	0.41
The development of digital media has made it easier to access information and education to the public.	0.11	3.40	0.37
Public awareness that the use of public transportation plays an important role in reducing air pollution.	0.11	3.60	0.41
Total			1.66
Threats			
Increase in the number of motor vehicles around the area due to urbanization and economic growth.	0.11	3.40	0.37
Air pollution in Jakarta is still high and may affect the air quality within the TOD area.	0.12	3.80	0.46
Changes in government policies that may hinder the development of pollution control programs.	0.11	3.40	0.37
Negative effects of air pollution on economic aspects.	0.10	3.20	0.33
Geographical and climatic conditions (e.g. dry season) that may exacerbate the concentration of pollutants in the area.	0.10	3.20	0.33
Total			1.85
Total EFAS			3.51

Table 3 SWOT Analysis Matrix of Air Pollution Control in Dukuh Atas Transit Area

	***Strength* (S)**	***Weakness* (W)**
	S1. The Dukuh Atas TOD area has a strategic location that supports high community activity. S2. Integrated infrastructure that supports connectivity and mobility efficiency in the Dukuh Atas TOD area. S3. The commitment of the DKI Jakarta government through SPPU (Air Pollution Control Strategy). S4. Community involvement in the development of the area. S5. Evaluation and monitoring of management are carried out regularly.	W1. There is no specific policy related to air pollution control in the development of TOD areas. W2. The high activity of private vehicles that dominate traffic around the area. W3. Lack of real-time air quality monitoring facilities in the TOD area. W4. Limited land in the Dukuh Atas TOD area. W5. Funding constraints that are still focused on infrastructure, with no specific allocation for air quality improvement.
***Opportunities* (O)**	**S-O**	**W-O**
O1.Potential collaboration with private sector and communities for air quality monitoring technology development. O2. Community support for new, stricter policies/regulations to improve air quality in transit areas.	1. Developing air quality monitoring technology in TOD areas through collaboration between the government and the private sector. 2. Building an integrated digital platform for real-time air quality monitoring and information that can be accessed by area users.	1. Proposing specific policies or regulations related to air pollution control in the development of TOD areas. 2. Implementing an Electronic Road Pricing (ERP) system in TOD areas.

O3. Development of digital media that facilitates access to information and education to the public. O4. Public awareness that the use of public transportation plays an important role in reducing air pollution.	3. Increasing the number of bus transitions from fossil fuel to electric buses.	3. Increasing socialization and education to the public to raise awareness of air pollution issues by utilizing the development of digital media. 4. Allocating a portion of revenue from parking and area levies for technology development and air quality improvement programs.
***Threats* (T)**	**S-T**	**W-T**
T1. The increase in the number of motor vehicles around the area due to urbanization and economic growth. T2. Air pollution in Jakarta, which remains high and can affect air quality within TOD areas. T3. Changes in government policies that could hinder the development of pollution control programs. T4. The negative impact of air pollution on the socio-economic aspects of the community. T5. Geographic and climatic conditions (e.g., dry season) that can worsen the concentration of pollutant contaminants in the area.	1. Expanding the motor vehicle access closure area in transit zones and establishing it as a Low Emission Zone (LEZ) with community participation in the design process. 2. Increasing the capacity and number of public transportation to enhance comfort and encourage public use. 3. Developing Air Quality Monitoring Stations in TOD areas. 4. Developing vertical green space solutions to increase air pollutant absorption in the area.	1. Developing a "transit reward" program that provides incentives for users of integrated public transportation to reduce the dominance of private vehicles. 2. Adding vegetation specifically to absorb pollutants in TOD areas. 3. Implementing an emission-based motor vehicle restriction system and automatic license plate recognition technology to reduce high-emission vehicles in TOD areas.

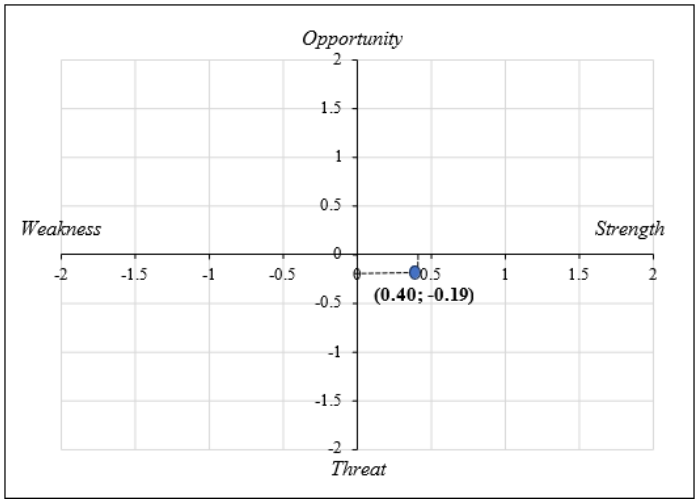

Fig. 2. Results of the SWOT Quadrant Analysis

Table 4 Prioritized strategies for improving air quality in TOD Dukuh Atas area.

Alternative Strategy	Linkage	Score	Total Score	Ranking
S-O STRATEGY				
Developing air quality monitoring technology in the TOD area through collaboration between the government and the private sector.	O1, S3, S5	1.14	3.35	3
Building an integrated digital platform for real-time air quality monitoring and information accessible to area users.	S4, O3, O4, 02	1.48		
Increasing the number of bus conversions from fossil fuel-powered to electric buses.	O2, S3	0.73		
W-O STRATEGY				
Proposing specific policies or regulations related to air pollution control in the development of the TOD area.	W1, O2	0.7	3.42	2
Implementing an Electronic Road Pricing (ERP) system in the TOD area.	W2, O1, O4	1.24		
Enhancing socialization and education to the public to raise awareness of air pollution issues by utilizing the development of digital media.	O3, W3	0.74		
Allocating a portion of revenue from parking and area levies for the development of technology and programs aimed at improving air quality.	W5, O2	0.74		
S-T STRATEGY				
Expanding the motor vehicle access restriction area in transit zones and designating it as a Low Emission Zone (LEZ) with community participation in the design process.	S4, T1, S3, S1	1.39	3.86	1
Increasing the capacity and number of public transportation services to enhance comfort and encourage public use.	S2, T4	0.66		
Developing Air Quality Monitoring Stations in TOD areas.	S5, T5	0.69		

Developing vertical green space solutions to increase air pollutant absorption in the area.	T5, T2, S2	1.12		
W-T STRATEGY				
Developing a transit reward program that provides incentives for users of integrated public transportation to reduce the dominance of private vehicles.	W2, T1	0.74	3.11	4
Adding vegetation specifically designed to absorb pollutants in TOD areas.	W4, T4, T5	0.92		
Implementing an emission-based motor vehicle restriction system and automatic license plate recognition technology to reduce high-emission vehicles in TOD areas.	W1, W2, T2, W5	1.45		

Based on the SWOT analysis that has been conducted, the strategy that can be implemented to improve air quality in transit areas is a diversification strategy that utilizes strengths to address threats. Some of the strategies outlined include expanding the area of motor vehicle access restrictions in transit areas and designating it as a Low Emission Zone (LEZ) with community participation in the design process, increasing the capacity and number of public transportation options to enhance comfort and interest in using public transport, developing air quality monitoring stations in each TOD area, and creating vertical green space solutions to improve air pollutant absorption in the area.

The first strategy that can be developed is to expand the area of motor vehicle access restrictions in transit areas and designate it as a Low Emission Zone (LEZ). According to research by[30], LEZ policies have a positive impact on environmental and social aspects. The LEZ policy has a strong correlation with social improvement and a fairly strong correlation with environmental aspects. The LEZ policy will encourage the use of public transportation and improve air quality in the surrounding area. Additionally, the positive impact on social aspects includes creating a more pleasant, interactive, safe, and comfortable environment for pedestrians.

LEZ is one of the most commonly used local strategies to reduce air pollution from traffic. Several cities have implemented LEZ by modifying the policy according to their specific conditions and priorities, including London, England; Shenzhen, China; Seoul, South Korea; and Lisbon, Portugal.[31] LEZ has been widely adopted in Western and Northern Europe, with over 100 zones spread across Scandinavia, the Netherlands, Germany, Italy, France, and Spain.[32] Several countries outside of Europe have also adapted the LEZ concept with various variations. For example, Beijing restricts heavy vehicles that produce high emissions;[33] Hong Kong has established special operational areas for franchised buses;[34] and New York City is planning a combination of LEZ and congestion pricing in Manhattan.[35] These examples emphasize that LEZ is an effective policy instrument for improving urban air quality, especially when implemented as part of a comprehensive sustainable transportation strategy.

The second strategy that can be developed is to increase the capacity and number of public transportation services to enhance comfort and interest among the public in using public transport. Research by[36], indicates that the development of mass transportation systems in Jakarta still faces various obstacles. Socially, the public's preference for private vehicles and a lack of education regarding the benefits of public transportation are significant challenges. Economically, limited budgets and fuel subsidies that make the cost of using private vehicles cheaper slow down the transition to public transport. Politically, policy instability and a lack of support from various stakeholders hinder progress. Additionally, land limitations and environmental pollution exacerbate the situation.

From a technical perspective, the suboptimal integration of transportation modes and inadequate facility quality also pose challenges. The lack of optimal incentives for public transportation users adds complexity to the development of mass transportation in Jakarta. According to research by[37], increasing the number of public transportation users has the potential to reduce traffic congestion by up to 20%, as the number of private vehicles operating on the roads decreases. As a result of the reduction in fossil fuel-powered vehicles, emissions released into the atmosphere also decline. In the long term, these efforts not only have a positive impact on environmental quality but also contribute to a decrease in health risks associated with air pollution. Research by[38] suggests that urban air quality in China can be improved if cities provide more buses for public transportation.

The third strategy that can be developed is to establish Air Quality Monitoring Stations (AQMS) in Transit Oriented Development (TOD) areas. According to the Jakarta Air Quality Monitoring Study Report released by the Jakarta Environmental Agency in 2023, the number of Air Quality Monitoring Stations (AQMS) currently does not adequately cover all areas of DKI Jakarta in a representative manner. As of 2023, there are 21 AQMS distributed throughout Jakarta, with plans to add 4 more AQMS in 2024, bringing the total to 25 AQMS by 2025. Although the number of AQMS has increased, the coverage of air quality monitoring still needs to be expanded to ensure a more accurate representation of air conditions across DKI Jakarta.

According to research by[39], despite the increase in the number of AQMS in Jakarta, the coverage of air quality monitoring is still not fully representative of the entire region. Therefore, there is a need to enhance the monitoring network by increasing the density of AQMS distribution. This step aims to broaden the monitoring coverage, improve the variety of data obtained, and enhance the accuracy of air quality analysis in Jakarta. Research by[40] indicates that air quality monitoring programs significantly reduce local

$PM_{2.5}$ concentrations by 1.325 mg/m³, and each additional air quality monitoring station will lead to a decrease of 0.154 mg/m³ in local PM2.5 concentrations. Ambient air quality monitoring in China began in the early 1970s, and as the number of monitoring stations increases, so does the air quality in those areas. Currently, China has a four-tier environmental monitoring system consisting of national, provincial, city, and county-level monitoring stations. Air pollutant monitoring in China has evolved from manual processes to comprehensive automated monitoring.

The fourth strategy that can be developed is to create vertical green space solutions to enhance air pollutant absorption in the area. To obtain certification as a green building, owners must meet specific guidelines and requirements that encompass the application of sustainability principles from the construction phase to operational use. The implementation of green building concepts results in sustainable positive impacts, which not only benefit the comfort and health of its occupants but also contribute to overall environmental preservation by improving energy efficiency and air quality. Meeting green building standards provides various benefits, such as reduced carbon emissions, increased property value, operational cost efficiency, and improved indoor environmental quality. These benefits not only support environmental sustainability but also enhance the comfort and health of occupants, making buildings more economically valuable.[41]

According to research by,[42] the application of Vertical Green Systems (VGS) in urban environments has the potential to create healthier and more sustainable surroundings. This study shows that the implementation of VGS can reduce NO_2 concentrations by up to 34.25% and PM_{10} by up to 42.5%, thereby contributing to improved urban air quality. In line with research by,[43] vertical green spaces in urban environments provide various benefits, including aesthetic and psychological aspects for users, as well as improving air quality, reducing global warming effects, and assisting in waste processing for buildings and their surroundings. Additionally, these green spaces also reduce noise and support energy efficiency, which has positive economic impacts through energy conservation.

CONCLUSION

This study confirms that despite various government interventions, air pollution in Jakarta, particularly in the Dukuh Atas Transit Oriented Development (TOD) area, remains a significant challenge. Through SWOT analysis, a diversification strategy that leverages strengths to address threats was found to be the most effective approach to improving air quality. The prioritized strategies recommended include expanding restricted access zones for motorized vehicles by implementing a Low Emission Zone (LEZ), increasing the capacity and number of public transportation options, developing air quality monitoring stations within the TOD area, and implementing vertical green space solutions. The implementation of these strategies is expected to significantly reduce private vehicle use and improve air quality in the TOD area, thereby supporting sustainable development goals and enhancing the quality of life for Jakarta's residents.

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