

Understanding Environmental Knowledge Among Road Users Through the Lens of the SES Approach

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ABSTRACT

This study examines the formation of social-ecological indicators among motor vehicle users related to pollutant emissions in Kuala Terengganu. Vehicle emissions are identified as one of the main contributors to urban air pollution; however, there is still a lack of comprehensive studies that integrate social and ecological aspects. This study employs the Social-Ecological Systems (SES) Framework to identify factors influencing user behavior, as well as related governance and infrastructure elements. A total of 11 informants were interviewed in a semi-structured manner, including users, government agency representatives, academic experts, and private industry representatives. Data were analyzed thematically based on codes derived from the SES framework. Initial findings indicate that factors such as user awareness, economic constraints, the effectiveness of existing policies, and access to green technology influence the formation of effective indicators. This study proposes several social-ecological indicators that local authorities can use to formulate more inclusive and community-based policies. These findings are expected to contribute to more sustainable carbon footprint management.

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Contribution/Originality: This study makes two significant contributions: first, it highlights the necessity of enhancing awareness, cooperation, and coordination among agencies working to reduce air pollutant emissions. Second, it emphasizes the need for

the government to expand and improve the efficiency of the public transport system while making economic investments to decrease reliance on private vehicles, ultimately promoting environmental sustainability.

1. Introduction

The world is currently experiencing rapid development, marked by the emergence of various new industries to meet societal needs. However, this progress has led to environmental deterioration due to human activities and urbanization, often without awareness of the consequences (Syifa Fauziah & Ratih Dwi Puspitasari, 2023). As a result, air pollution has become a pressing global issue that demands attention. This issue is particularly significant because it impacts the quality of life across health, economic, and lifestyle dimensions, affecting developed, developing, and underdeveloped countries alike (Rentschler & Leonova, 2023). According to the World Health Organization (WHO), air pollution is responsible for 4.2 million premature deaths worldwide, primarily due to the spread of fine particulate pollutants that can affect the respiratory system (World Health Organization [WHO], 2024).

In Malaysia, the increasing number of motor vehicles has become one of the primary contributors to air pollution. According to the Department of Statistics Malaysia (2022) the number of registered motor vehicles surged to over 33 million units in 2022, encompassing private cars, motorcycles, vans, and light commercial vehicles. This growth is driven by society's heavy reliance on private vehicles, particularly due to the limited public transport system outside the Klang Valley. A report by the Department of Environment (DOE) indicates that motor vehicles emit pollutants such as carbon monoxide (CO), nitrogen dioxide (NO₂), and particulate matter (PM10), which directly impact air quality and public health (Department of Statistics Malaysia, 2022).

Although the issue of vehicle pollutant emissions has been extensively studied technically, approaches that combine social and ecological dimensions are still underexplored at the local level (Mashahadi et al., 2023; Department of Statistics Malaysia, 2022). Therefore, the use of the Social-Ecological Systems (SES) framework is considered appropriate to understand the interactions between users, governance, and the environment in this context (Ostrom, 2009; Partelow, 2018). This study aims to identify forms of social capital and ecological capital among motor vehicle users related to the issue of air pollutant emissions in Kuala Terengganu and to propose a social-ecological indicator framework for more sustainable mobility management. This article is organized according to the introduction, materials and methodology, results and discussion, and conclusions.

2. Research Methods

This study employed an interpretive qualitative design to gain a deeper understanding of how motor vehicle users and stakeholders perceive vehicle emissions. This approach enabled the researcher to examine the experiences, understandings, and meanings that individuals attribute to the issue (Islam & Aldaihani, 2021). This design was selected because it emphasizes subjective interpretations of social reality and allows the researcher to explore informants' perspectives on the social and ecological factors that influence behavior and awareness of air pollution.

2.1. Study Area

The study area is located around Kuala Terengganu, the capital of Terengganu on the East Coast of Peninsular Malaysia. Kuala Terengganu is a developing coastal area characterized by moderate population density and rapid infrastructure growth. This area was selected due to its high motor vehicle usage, which results from a limited public transport system and the community’s reliance on private vehicles as the primary mode of mobility (Department of Statistics Malaysia, 2022). This reliance places pressure on the local environment, particularly concerning deteriorating air quality (Department of Statistics Malaysia, 2022). Geographically, as shown in Map 1, the area encompasses urban and suburban zones with variations in consumer behavior and awareness of air pollution issues. Major economic activities, such as government administration, education, the service sector, and tourism, also contribute to increased traffic, making Kuala Terengganu a relevant site for socio-ecological studies related to vehicle pollutant emissions.

2.2. Data Sources

Data for this study were collected through semi-structured interviews with 11 informants selected via purposive sampling. The informants came from diverse backgrounds, including seven motor vehicle users, one lecturer serving as an academic expert, one representative from a government agency, and two representatives from the private sector of automobile manufacturing. This study received ethical approval from Universiti Malaysia Terengganu and all participants gave their consent to participate in the interview session. This selection aimed to capture a range of perspectives based on their roles as actors in the social-ecological system (McGinnis & Ostrom, 2014).

Part A, Part B, and Part C. Part A contained personal information about the informants, such as gender, age, race, marital status, occupation, academic qualifications, vehicle type, and daily driving time. Part B focused on questions related to socio-ecological indicators, which were divided into B1 (sociology) and B2 (ecology). Finally, Part C focused on the socio-ecological framework, which was divided into three parts: Part I (Draw), Part II (Interpret the picture), and Part III (Concept map). A sample text of the questionnaire questions is included in Table 1.

Table 1: Example of 3 text questions from 5 questionnaire items based on the SES framework, as answered by respondents

PART B: ECOLOGICAL SOCIAL INDICATORS	
Actors(A)	1) Who are the main actors influencing motor vehicle users' decisions regarding pollutant emissions in Kuala Terengganu? (A1) 2) How does your salary affect your choice of motor vehicle? (A2) 3) Do vehicle maintenance costs, such as servicing, fuel, and insurance, strain your household finances? (A3)
B1: Sociology	1) How do government agencies, such as the Department of Environment (DOE) and Local Authorities (LAs), collaborate to monitor and control pollutant emissions? (GS1)
Governance System (GS)	2) Who are the key actors involved in the development of pollutant emission management policies, and how do they interact? (GS3)

	3) What is the process for involving various parties including vehicle users, local governments, NGOs, and industry in the formation of regulations related to pollutant emissions in Kuala Terengganu? (GS6)
	1) What are the main factors driving the community in Kuala Terengganu to choose motorized vehicles over public transport or other modes of transportation? (RS1)
	2) Which types of vehicles are included in the transport system that contributes to pollutant emissions? (RS2)
Resource System (RS)	3) To what extent is the existing public transport system able to reduce dependence on private vehicles in Kuala Terengganu? (RS3)
B2: Ecology	1) In your opinion, how does the use of private vehicles contribute to air pollution in Kuala Terengganu? (RU1)
	2) Have you ever considered reducing your use of motor vehicles to decrease pollutant emissions? (RU5)
Resource Unit (RU)	3) How do changes in transport infrastructure, such as the introduction of electric buses or bicycle lanes, impact the rate at which conventional vehicles are replaced with environmentally friendly ones? (RU3)

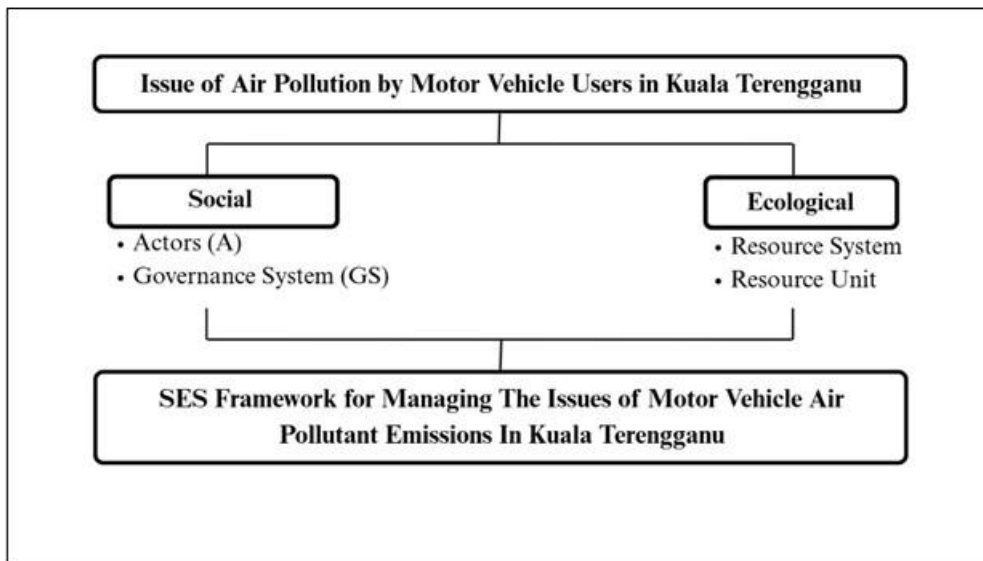
All these question texts were tested for construct and content validity, as well as reliability, by lecturers who experts in air pollution issues at Universiti Malaysia Terengganu are. All sessions were recorded and transcribed verbatim for analysis. Data analysis was conducted thematically, using the Social-Ecological System (SES) framework as an initial coding guide. The analysis process involved repeated readings of the transcripts, identification of themes, and categorization according to SES components (Biggs et al., 2021).

2.3. Principles for Using the Social-Ecological System Framework (SES)

This study uses the Social-Ecological Systems (SES) framework developed by Ostrom (2009) to understand the complex interactions between humans and their environment regarding pollutant emissions from motor vehicles. This framework emphasizes the interaction between social systems (actors and governance systems) and ecological systems (resource systems and resource units), which together influence the outcomes of shared resource management.

In this study, the SES framework, as shown in Figure 1, is employed to analyze the factors that shape vehicle user behavior, including environmental awareness, access to green technology, and responses to government policies. The main components of the framework that serve as coding guides are based on the recommendations within the SES framework. This approach was chosen due to the flexibility of the SES framework in various contexts, such as vehicle management, air pollution, and systems-based thinking (Nagel & Partelow, 2022). By using this framework, researchers can develop a more comprehensive understanding and propose social-ecological indicators that are relevant to the local environment in Kuala Terengganu.

Figure 1: Construction of a social-ecological systems (SES) framework based on case studies using the method introduced by Ostrom (2009).

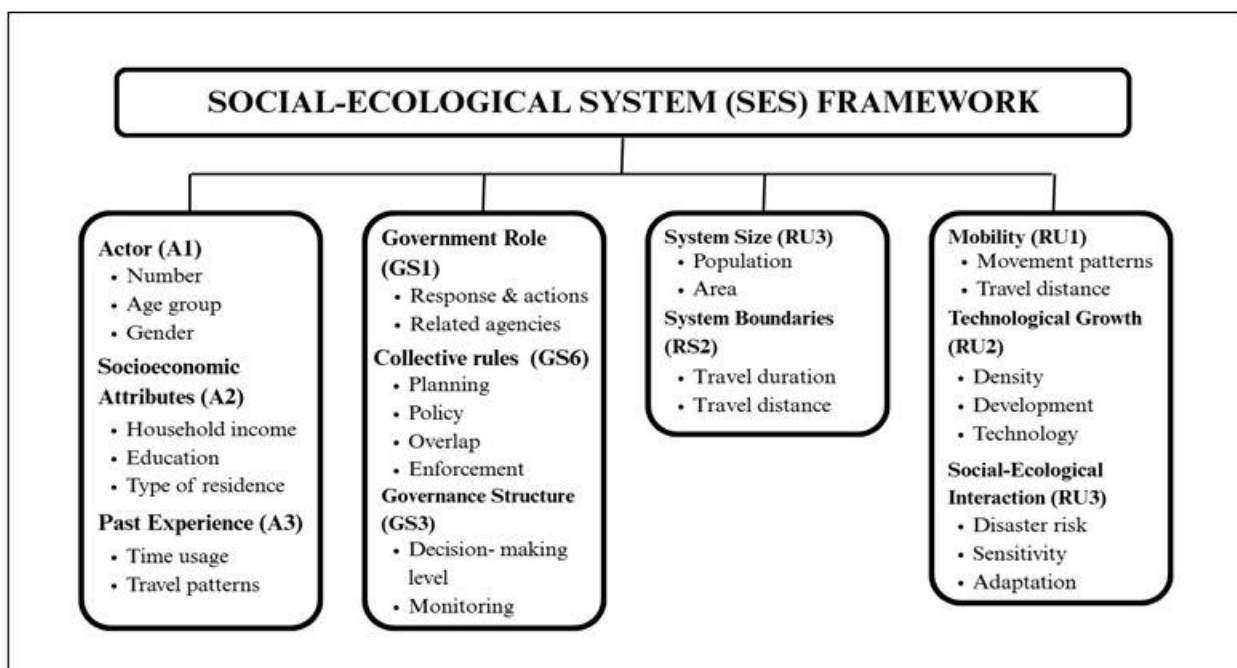


Source: Ostrom (2009)

3. Results

This section presents the results of the study obtained from semi-structured interviews with 11 informants from the consumer, expert, private sector, and government agency sectors. The analysis was conducted using the Socio-Ecological Systems (SES) framework, as shown in Figure 2.

Figure 2: Mapping themes that emerged from the output of this study using the Ostrom (2009) method



Source: Ostrom (2009)

3.1. Awareness among Actors regarding issues related to social capital.

This section discusses the social elements that influence pollutant emissions from motor vehicles, focusing on the roles of various actors, such as government agencies, consumers, and the private sector, as well as the governance of policies related to mobility and the environment.

The study findings indicate that consumer awareness of the roles of key actors, such as the Road Transport Department (JPJ) and the Department of Environment (DOE), is still low. Most informants associate the JPJ only with licensing and vehicle management, without realizing that this agency is also directly involved in vehicle emission inspections. Meanwhile, the DOE is better known for its involvement in river monitoring and open burning than for air quality monitoring.

"I know JPJ takes care of licenses and summonses, but regarding the black smoke from the car, I'm not sure who should be monitoring it."

[Actor 1-user]

"People know the Department of Environment because it monitors factories and rivers. But when it comes to car emissions, many people don't know that it's involved."

[Actor 2-user]

In addition, the role of vehicle manufacturers and private parties, such as Perodua and Mercedes, is still considered limited in supporting the transition to green technology. Although these companies have introduced environmentally friendly models, informants noted that promotion and consumer information are still not widespread, particularly in rural areas like Kuala Terengganu.

Regarding governance, several informants from various agencies highlighted challenges in coordinating actions among them. The JPJ, DOE, and local authorities are perceived to carry out their respective tasks in isolation, lacking a joint action plan or integrated campaign related to vehicle emissions.

"Sometimes we go out into the field to do programs, but the other party doesn't know. If there is closer cooperation, the effect will certainly be stronger."

[Actor 8 – Government Officer]

In addition, enforcement issues arise when vehicle inspections are not conducted consistently. Consumers stated that inspections carried out by Agency X are sometimes too lenient and do not adequately pressure vehicle owners to ensure their vehicles are in good condition regarding emissions.

"Agency X only looks at the outside. Sometimes, even a smoky car can be released. It's not even very tight."

[Actor 7- user]

Public awareness of policies such as the National Automotive Policy (NAP) and incentives for electric vehicles (EVs) remains low. A study by Mashahadi et al. (2023) reveals that while millennials, who are more concerned about environmental issues, should be inclined to adopt EVs, the adoption rate in Malaysia remained below 3% in 2021. This is despite government efforts to promote EV use for sustainable development. Additionally, the lack of clear information for consumers leaves them unmotivated to switch to more sustainable practices or choices (Mashahadi et al., 2023).

3.2. Awareness among actors regarding issues related to ecology capital

The resource system refers to the physical structures and facilities that comprise the mobility environment in Kuala Terengganu. Interviews with users indicated that the public transport network in the city remains limited in coverage, frequency, and efficiency. Public buses are perceived as untimely and lacking in comfort, resulting in a high reliance on private vehicles.

"The bus is slow, and the timing is unpredictable. If you want to go to work or conduct important business, you really can't rely on the bus."

[Actor 11- User]

In terms of road infrastructure, major routes such as Jalan Sultan Mahmud and Jalan Lapangan Terbang often experience congestion during peak hours. Additionally, there are no dedicated lanes for green vehicles or alternative transportation, such as bicycles. Several informants noted that urban planning prioritizes regular motorized vehicles over low-carbon transportation systems.

"There are a lot of cars near the city, and many new roads have been built. But for people riding bicycles or using buses, there aren't many special lanes."

[Actor 3- User]

In addition, the geographical layout of Kuala Terengganu, which includes both urban and rural areas, presents challenges for implementing an efficient public transport system. Residents in suburban areas must travel long distances to reach the city center, making the use of private vehicles a daily necessity.

Moreover, resource units small objects or entities within the system—encompass the type of vehicle, the method of use, and the technology employed. Studies indicate that most users in Kuala Terengganu still rely on conventional vehicles powered by petrol and diesel, particularly used cars and motorcycles. Economic factors are the primary reason they are unable to transition to more environmentally friendly vehicles.

"I know EVs are good, but the price is really unaffordable. I only use an old car, and even that is outdated."

[Actor 4- User]

Motorcycle use is more prevalent among young users and informal sector workers. However, motorcycles also contribute significantly to carbon emissions, as most do not undergo regular emissions inspections.

"Motorcycles are convenient and economical, but if they break down, many people don't service them properly. Even if black smoke comes out, it doesn't really matter."

[Actor 2- User]

In terms of technology, hybrid and electric vehicles have yet to gain traction in the region. Some of the main obstacles include a lack of charging stations, high maintenance costs, and insufficient technical knowledge. According to informants from the private sector, the demand for electric vehicles (EVs) in Terengganu remains low compared to larger cities such as Kuala Lumpur.

"People in Terengganu haven't bought many EVs. Even if they do, it's hard to find a place to charge them. The cost is also high."

[Actor 5- private agency]

Vehicle usage patterns indicate that most residents travel short distances to work, markets, and schools, but do so individually. This suggests that even if the journeys are not long, repeated inefficient vehicle use still significantly impacts the environment in terms of carbon emissions.

Overall, the ecological capital in Kuala Terengganu demonstrates an imbalance between mobility needs and the system's capacity to support environmental sustainability. Incomplete transport infrastructure and technologically inefficient vehicle use have contributed to continued increases in pollutant emissions from this sector. Improvements to the resource system (RS) and resource unit (RU) are urgently needed to facilitate the transition toward more sustainable urban mobility.

4. Study Limitations and Recommendations

Although this study provides an overview of the formation of social-ecological indicators related to pollutant emissions from motor vehicles in Kuala Terengganu, several limitations must be acknowledged. The first limitation is the sample size, which is restricted to only 11 participants and does not adequately represent the entire population. Additionally, the informants did not provide clear information, and obtaining good cooperation proved challenging.

Another limitation is the study's geographical scope, which focuses solely on the Kuala Terengganu area. Consequently, the findings of this study cannot be generalized to other states without considering variations in urban structure, transportation infrastructure development, and environmental awareness specific to each locality. Finally, this study does not directly evaluate quantitative emission data; instead, it is more qualitative in nature, examining perceptions, experiences, and recommendations from social and ecological perspectives.

As a suggestion for further study, the government, including the Department of

Environment (DOE) and other agencies such as the Kuala Terengganu City Council, should establish collaborations with the private sector to address air pollution caused by emissions from motor vehicles. This partnership could effectively control pollutant emissions. Additionally, public transportation facilities in Kuala Terengganu need to be expanded and improved. This expansion is a crucial strategy for managing pollutant emissions and maintaining environmental quality. The availability of adequate public transportation can encourage the public to choose public transit over private vehicles.

5. Conclusion

This study shows that the issue of pollutant emissions from motor vehicles in Kuala Terengganu is influenced by interrelated social and ecological factors. Through the application of the Social-Ecological System (SES) framework, two main dimensions, namely social capital and ecological capital, have been identified to influence the level of awareness and actions of vehicle users in dealing with air pollution. The findings show that there is a high dependence on private vehicles due to inefficient public transport infrastructure and lack of incentives towards the use of green vehicles. In addition, cooperation between agencies is also seen as weak, while the public education approach is still not comprehensive. Therefore, this study proposes the implementation of digital awareness campaigns, strengthening governance between JPJ and DOE, and improving the public transport system as among the intervention measures that can be implemented. The results of this study can assist in the development of more responsive local social-ecological indicators and contribute to more sustainable urban mobility management policies.

Ethics Approval and Consent to Participate

The researchers used the research ethics guidelines prepared by the Research Ethics Committee of Universiti Malaysia Terengganu (UMT). All procedures performed in this study involving human subjects have been carried out in accordance with the ethical standards of the institution's research committee. Permission and consent to participate in the study were also obtained from all study participants

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Conflict of Interest

The authors reported no conflicts of interest for this work and declared that there is no potential conflict of interest with respect to the research, authorship, or publication of this article.

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