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Association Between Green Rural Road Elements and Socioeconomic Development Indicators in Rural Areas

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Abstract

Sustainable development is defined as the development that meets the needs of the present without compromising the ability of future generations. In Malaysia, particularly in rural areas, the networks comprise the largest proportion of roads in the country, making efficient road development critical for economic progress. However, such development has significantly impacted the environment, contributing to substantial ecological disruption and affecting the quality of life in local communities throughout the road lifecycle. Therefore, the adoption of sustainable approach by implementing green elements in the development and operation of rural road infrastructure is the ideal way forward to concurrently meet economic, social and environmental needs. Accordingly, this study seeks to identify the green rural road elements that should be considered in the development of rural roads. It also investigates which green elements can potentially contribute to socioeconomic development in rural areas. A quantitative method was employed, using a questionnaire survey as the research instrument to determine the significant green rural road elements. Data collection was conducted using the census method, resulting in the return of 63 completed questionnaires. The data were analyses using Goodman Kruskal's Gamma. The analysis revealed that seventeen (17) green rural road elements were statistically significant and showed a strong positive association with at least one of the socioeconomic development indicators studied. These proposed elements are expected to enhance stakeholder understanding and offer practical guidance for improving the sustainability of rural road infrastructure projects. Ultimately, this contributes not only to environmental conservation but also to the advancement of social and economic well-being in rural communities.

1. Introduction

Nowadays, the implementation of green practice has become a favourable method in relation to road construction as these vital infrastructure assets give significant impact on environment and humans, in general. Thus, efficient and sound infrastructure development, such as rural road construction and upgrading the rural road networks that link rural areas to urban areas are a necessity. Resilient infrastructure should focus on both rural and urban areas without being prone towards urban areas. Additionally, rural roads play an important role in socioeconomic development by providing access to economic and social activities [1]. According to Robinson [2], rural roads generally contribute to development by facilitating local and international trade, improving access to jobs, education, healthcare, and by providing other relevant services worldwide. Robinson further emphasizes that an effective and efficient road transportation system can lead to higher incomes, greater economic well-being, increased personal mobility and facilitated economic growth. In return, this assists in reducing poverty and further contributes to social development. In many developing countries, investment in rural road infrastructure has continued to be a priority, as structured rural road plays a catalyst role in socioeconomic development and provides access to amenities such as education, healthcare, marketing and many other important assets. However, road development and operations often involve large-scale activities that can have long-term effects on both humans and the environment, including significant ecological impacts and disruptions to the local community's quality of life throughout the road's lifecycle. Rural road construction also can undeniably lead to issues such as land fragmentation and deterioration of cultivable land areas, which in turn affect agricultural production [3]. Malik et al., [5] in support of this view, elaborated on the impacts of road development, which includes increased traffic congestion, elevated levels of air pollution and noise, damage to natural resources such as soil erosion, loss of biodiversity and displacement of wildlife, increased land use, fragmentation of habitats and acidification of soil. Therefore, the adoption of a sustainable approach by implementing green elements in the development and operation of rural road infrastructure is the ideal way forward to address these issues and concurrently meet the overall economic, social and environmental needs.

2. Socioeconomics

The earliest and pioneer measurement of socioeconomic development is the Gross Domestic Product (GDP). However, GDP is widely acknowledged to be a poor measure of social well-being and is only based on one specific indicator, which is one's income [6]. GDP is considered not adequate to measure people's well-being, mainly because it does not account for other relevant socioeconomic issues such as family, quality of life, human happiness and satisfaction, environmental deterioration, natural and human capital, income distribution and defensive expenditure [7]. The composite of Human Development Index (HDI) was then created by M. ul Haq in 1990 with the help and advice of A. K. Sen, an Indian economist and philosopher who established the first assumptions of comprehensive measurement of socioeconomic development [8]. Later, the HDI underwent several modified socioeconomic assessments that included additional indicators, which significantly contributed to the development of social communities. These include the Composite Global Well-Being Index (CGWBI), Happy Index and the Better Life Index by Organisation for Economic Co-operation and Development (OECD).

2.1 Socioeconomic Development Indicators

Socioeconomic development encapsulates the dynamic process of change (Causes and contributing factors) as well as the state of development (performance and outcomes) [9]. Many indicators have a theoretical assumption that there is a causal chain of relationships to be measured by different types of indicators. However, due to the complexity and the lack of strong theoretical underpinnings of precise interrelations between different socioeconomic issues, it is rather difficult to untangle the web of causal relationships [9]. Therefore, the interpretation of socioeconomic development was based on the suitability of the elements itself to socioeconomic development in rural areas. Table 1 summarizes the indicators used in defining socioeconomic development indicators based on socioeconomic assessments and several scholar definitions.

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Table 1 *Socioeconomic development indicator and their references*

Socioeconomic Development Indicators	References
Income	HDI, OECD, CGWBI, Happy Index, [10], [11], [12]
Employment	HDI, OECD, CGWB, [13],[14], [15],[16],[17],[12],[18]
Education	OECD, CGWBI, [14],[20],[17],[12],[18],[19]
Health	HDI, Happy Index, CGWBI, [14],[20],[18]
Safety	OECD, CGWBI, [21],[19]

Based on Table 1, it can be summarized that most scholars use income, employment, education, health, and safety as indicators for socioeconomic development. Evidently, these indicators measure the socioeconomic development of rural communities and can be used as part of a broader strategy to address rural problems and concerns at the village level [12];[18];[19];[16]. In this study, five (5) indicators were selected, which includes income, employment, health, education, and safety. Based on the researcher's interpretation, in terms of employment level, it can be defined as the increasing number of job opportunities generated through the implementation of a proposed green rural road network element. Additionally, the potential contributions of green rural road network elements on local business and economic activities can be interpreted by examining the increase in income levels. Furthermore, in terms of road safety, it represents how the elements of the green rural road network can potentially minimize hazards for road users and reduce the number of accidents and fatalities. Regarding health, the interpretation is based on how these elements contribute to human comfort and improve the overall quality of living. Lastly, for education, it represents how the green rural road network elements facilitate access to educational institutions such as schools and higher education institutions for rural communities.

3. Methodology

In this study, the researcher employs the quantitative method using a questionnaire survey as an instrument. The questionnaire survey is designed using ordinal variables using a Likert scale: Strongly Agree = 5, Strongly Disagree = 1, for both the dependent and independent variables. For data collection purposes, the census method was applied. A total of 119 questionnaires surveys were distributed; however, only 63 questionnaires were successfully collected in return. The respondents included individuals working in the Public Works Department (JKR), District Office (PBT) and Road Engineering Consultants in Perak, Negeri Sembilan and Johor. The data from this main survey were then analyses using IBM Social Statistical Package for Social Science (SPSS) version 26.0. Goodman and Kruskal's Gamma Analysis method was applied in the overall analysis and interpretation of the results. The formula for Goodman Kruskal Gamma is given by Eq. (1);

$$\gamma = \frac{C-D}{C+D} \tag{1}$$

where:
C = number of concordant pairs (pairs ranked in the same direction)
D = number of discordant pairs (pairs ranked in opposite directions)

Gamma ranges from −1 to +1, where:
γ=+1 indicates perfect positive association,
γ=−1 indicates perfect negative association,
γ=0 indicates no association

For the questionnaire survey, the respondents were requested to rate the importance of 17 green rural road networks elements for the development of green rural road and concurrently rank their level of agreement on the association between green rural road networks elements and socioeconomic development indicators. The seventeen elements stated are;

i. Continuous quality improvement of road
ii. Road safety audit activities
iii. Water drainage system
iv. Stormwater runoff activity
v. Preservation of ecological considerations.
vi. Preservation of habitat and ecological connectivity
vii. Preservation of agriculture area
viii. Limitation usages of carbon emission
ix. Usage of green pavement material
x. Usage of porous pavement
xi. Implementation of shady areas with trees
xii. The implementation of pedestrian access
xiii. Provision of motorcycle or bicycle access
xiv. Provision assesses education
xv. Usage of LED streetlight
xvi. Erosion control activities
xvii. Promoting tourism

Based on the analysis, coefficient alpha (α) for all computed 17 elements of green rural road networks was 0.959. The result indicates that the overall reliability of data collected in this main survey was excellent. The value of 0.959 indicates an excellent consistency of elements that have been analyzed [22]. These 17 elements were tested in terms of their reliability using the Cronbach alpha-value based technique.

4. Analysis

In this study, seventeen (17) elements were further analyzed using Goodman and Kruskal's Gamma to examine the association between two variables: green rural road network elements and socioeconomic development indicators. Table 2 presents the Gamma coefficients between these two variables and the elements with significant values are highlighted in grey.

In this study, only Gamma coefficients (γ) of 0.5 and above were considered, as this value indicates a strong positive association between the green rural road elements and socioeconomic development indicators. Additionally, a p-value of less than 0.05 was used to indicate a significant association result [23]. Based on the analysis, it was found that 17 green rural road elements showed strong positive association with at least one of the socioeconomic development indicators, as highlighted in Table 2. From the analysis, it is evident that these seventeen (17) elements were significant and had a strong positive association with at least one of the socioeconomic development indicators, namely, income, employment, health, education and safety. This shows that the elements studied can potentially deliver significant contribution to socioeconomic development in rural areas and concurrently benefit the environment. Identically, the green concept elements not only lessen the burden on mother nature, but it can also significantly improve the quality of life of people living within various communities. Green practices and sustainable designs have been proven to reduce raw material consumption, carbon footprint, water consumption, greenhouse gas emissions, environmental pollution, solid waste generation, and the usage of fuels and energy, while also contributing to the conservation of habitats and wildlife [24].

Furthermore, Engert et al.,[25] listed several impacts of road development projects, which include the depletion of natural resources, an increase in stormwater runoff, a loss in water quality, an increase in noise and air pollution, fragmentation of wildlife habitat, and disruption of natural processes. In addition, rural road construction also causes issues such as land fragmentation and deterioration of cultivable land areas, which can significantly affect agricultural production [26]. Kunkuro et al., [27] have also highlighted the impacts of road development, including increased traffic congestion, air pollution, and noise levels, as well as damage to natural resources such as soil erosion and loss of biodiversity. Therefore, sustainable elements should be implemented through rural road operation and maintenance as these green elements will reduce the significant impact on the environmental, social and economic aspect as it may exert an influence on socioeconomic development activities by maximising access to basic facilities such as educational institutions and health centres, enhancing the local natural and identity through the iteration on the local landscape, and improving the quality of life through these elements. These green elements also provides employment opportunities through operation and maintenance activities. Undeniably, the green initiative should be implemented for rural road infrastructure development, which can benefit socioeconomically and environmentally.

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Table 2 *Gamma coefficient between green rural road network elements with socioeconomic development indicators development indicators*

Element		Socioeconomic Development Indicators					
		Income Level	Employment Level	Safety	Health level	Education level	Attributes
Usage of green pavement material (C18)		0.220	0.223	0.322	0.511	0.199	Material
	Sig Value	0.139	0.144	0.079	<0.001	0.168	
Usage of porous pavement (C19)		0.108	0.393	0.519	0.108	0.094	
	Sig Value	0.315	0.063	<0.001	0.109	0.461	
Preservation agriculture areas (C16)		0.536	0.241	0.187	0.221	0.085	Community
	Sig Value	<0.001	0.256	0.341	0.158	0.640	
Promoting tourism (C28)		0.668	0.331	0.203	0.269	0.018	
	Sig Value	<0.001	0.067	0.091	0.084	0.154	
Limitation usages of carbon emission (C17)		0.225	0.331	0.257	0.626	0.122	Carbon
	Sig Value	0.140	0.068	0.089	<0.001	0.185	
Stormwater runoff activity (C12)		0.225	0.231	0.620	0.607	0.156	Runoff
	Sig Value	0.107	0.095	<0.001	<0.001	0.319	
Erosion control activities (C26)		0.241	0.506	0.612	0.501	0.185	Erosion
	Sig Value	0.081	<0.001	<0.001	<0.001	0.116	

Table 2 *Gamma coefficient between green rural road network elements with socioeconomic development indicators development indicators (cont'd)*

Element		Socioeconomic Development Indicators					Attribute
		Income Level	Employment Level	Safety	Health level	Education level	
Implementation of shady area with tall trees (C20)		0.191	0.255	0.247	0.586	0.181	Ecosystem
	Sig Value	0.184	0.062	0.082	<0.001	0.192	
Preservation of habitat and ecological connectivity (C15)		0.226	0.368	0.522	0.127	0.067	
	Sig Value	0.102	0.092	<0.001	0.350	0.632	
Preservation of ecological considerations (C13)		0.189	0.331	0.609	0.194	0.178	
	Sig Value	0.215	0.078	<0.001	0.223	0.246	
Water drainage system (C11)		0.257	0.303	0.623	0.197	0.071	Water
	Sig Value	0.071	0.065	<0.001	0.117	0.463	
Provision of motorcycle and bicycle access (C23)		0.258	0.383	0.645	0.289	0.071	Facilities
	Sig Value	0.088	0.065	<0.001	0.075	0.599	
The provision of access to educational institution (C24)		0.052	0.219	0.538	0.289	0.549	
	Sig Value	0.716	0.121	<0.001	0.101	<0.001	
Implementation of Pedestrian's Access (C22)		0.092	0.256	0.647	0.188	0.060	
	Sig Value	0.572	0.123	<0.001	0.275	0.690	
Road Safety audit (C5)		0.130	0.546	0.699	0.259	0.046	Safety
	Sig Value	0.225	<0.001	<0.001	0.115	0.798	
Continuous quality improvement of road (C4)		0.219	0.500	0.526	0.202	0.006	
	Sig Value	0.121	<0.001	<0.001	0.143	0.968	

Table 2 *Gamma coefficient between green rural road network elements with socioeconomic development indicators development indicators (cont'd)*

Element		Socioeconomic Development Indicators					
		Income Level	Employment Level	Safety	Health level	Education level	
Usage of green pavement material (C18)		0.220	0.223	0.322	0.511	0.199	Material
	Sig Value	0.139	0.144	0.079	<0.001	0.168	
Usage of porous pavement (C19)		0.108	0.393	0.519	0.108	0.094	
	Sig Value	0.315	0.063	<0.001	0.109	0.461	
Preservation of agriculture areas (C16)		0.536	0.241	0.187	0.221	0.085	Community
	Sig Value	<0.001	0.256	0.341	0.158	0.640	
Promoting tourism (C28)		0.668	0.331	0.203	0.269	0.018	
	Sig Value	<0.001	0.067	0.091	0.084	0.154	
Implementation of shady area with tall trees (C20)		0.191	0.255	0.247	0.586	0.181	Ecosystem
	Sig Value	0.184	0.062	0.082	<0.001	0.192	
Preservation of habitat and ecological connectivity (C15)		0.226	0.368	0.522	0.127	0.067	
	Sig Value	0.102	0.092	<0.001	0.350	0.632	
Preservation of ecological considerations (C13)		0.189	0.331	0.609	0.194	0.178	
	Sig Value	0.215	0.078	<0.001	0.223	0.246	
Usage of LED street light (C25)		0.313	0.301	0.582	0.408	0.043	Lighting
	Sig Value	0.081	0.092	<0.001	0.068	0.826	

5. Conclusion

Overall, the findings demonstrate a strong positive association between the studied green road elements and socioeconomic development, highlighting the importance of integrating sustainability into infrastructure projects. By focusing on the social, economic, and environmental pillars, the research enhances the understanding of sustainable rural road systems. In conclusion, this study contributes valuable insights into sustainable infrastructure development and offers practical solutions for advancing rural road projects in Malaysia and beyond. Sustainable elements should be implemented through rural road operations and maintenance as green elements will reduce the significant impact on all environmental, social and economic aspects. The element of road exerts an influence on socioeconomic development activities by maximizing access to basic facilities such as educational institutions and health centers, enhancing the local nature and identity through the iteration on the local landscape, and improving the quality of life and human safety through these green road elements. It also provides employment opportunities through operation and maintenance activities. Therefore, the study can undeniably conclude that, the green initiative should be implemented by the Malaysian government, mainly for rural road infrastructure development, which can further benefit both the socioeconomic and environmental aspects effectively.

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Conflict of Interest

Authors declare that there is no conflict of interest regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***Methodology, formal analysis, investigation, resources, writing, original draft, visualization:*** *N A Mustafa;* ***Data curation, writing – review & editing:*** *V Munikanan, R Zakaria and M H S Abd Rashid.*

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