International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 07 Issue: 10 | October - 2023 SJIF Rating: 8.176 ISSN: 2582-3930

Pollution Prevention as a key to Sustainability: A Case of Polluted Industrial Region in Kerala

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Industries are a vital part of every country's economic development, but they are also the major source of pollution. Pollution from industries and power plants are closely connected to the sustainability of a city or region as they have an impact on air quality, weather, health, and overall quality of life. The main aim of this paper is to determine how sustainability can be improved and enhanced by prevention of pollution, through a case study of polluted industrial region in Kerala. In Kerala, the Eloor-Edayar Industrial Belt in Ernakulam district, the state's largest industrial belt, is the primary region affected by industrial pollution. Unsustainable development in the region has damaged the environment as well as people's health, quality of life, and livelihoods, triggering a series of protests against industries. From the broad understanding of existing scenario of the study region through secondary data, public opinions and discussion with experts, this research investigates the issues caused by industrial pollution to the surrounding communities. . Various types of industrial pollution sources (water, air, land) and their environmental, health, and socio-economic repercussions are evaluated and assessed in relation to the region's long-term sustainability. The study's conclusion, based on the research and findings, aims to establish solutions for addressing industrial pollution in order to enhance the region's sustainability.

Introduction

Industrialization refers to the socioeconomic, political, and cultural transformations that occur in human societies. The current trend of industrialization in developing countries has a massive impact on both natural and man-made environments. Pollution sources are increased as a result of industrialization, polluting the air, water, and soil. Concerns about future industrialization have risen due to a lack of environmental planning and management approaches. With this goal in mind, the most crucial drive of industrialization is environmental protection. Air pollution, wastewater, hazardous chemicals, toxic waste, and greenhouse gas (GHG) emissions from industrial regions have massive impacts on the local, regional, and global environment, endangering future generations' health. The Eloor industrial belt in Kerala, according to the worldwide environmental organization "Greenpeace (2003)," is one of the world's "top hazardous hot spots," resulting in rising rates of mortality and diseases in Eloor near Kochi. More than 17.35 ml of extremely contaminated effluents are released into the river Periyar every day, making Eloor the world's 35th most hazardous hotspot (8). Ground water contamination, flora and fauna degradation, genetic disordering, and livelihood issues (i.e., loss in fishing wealth and agricultural land fertility) on the banks of the Periyar River caused by manufacturing and biochemical industries. The Eloor Industrial Area has been

identified as one of the priority areas that need immediate restoration (9). This paper intends to investigate the issues caused by industrial pollution in Eloor industrial region in terms of sustainability as well as to propose strategies to improve sustainability.

Methodology

The research examines the ways by which sustainability can be improved by combating the industrial pollution. The study begins with the understanding of concept of sustainability and how it is connected to industrial pollution. From the literature studies, the concept of sustainable industrial development and the major challenges faced by industrial regions in terms of sustainability are studied. The study area chosen for the research is a major region affected by industrial pollution in context of Kerala. After understanding the profile of the study area which includes its location, connectivity, industrial scenario and land use from literatures, detailed study of area is carried out on the basis of reconnaissance survey, public opinions and discussion with experts. It focuses on environmental, health and socio economic impacts of industrial pollution to the surrounding communities. From the detailed study of the region, major Strengths, weaknesses, opportunities and threats of the region has been identified. On the basis of analysis and inferences, strategies for improving the sustainability of the region are formulated. The scope of the study is extended to the understanding of environmental, health and socio-economic impacts of industrial pollution and to examine the relation between sustainability and industrial pollution within a planning perspective in order to ensure sustainable development of the region. The study is limited to the analysis of sustainability and industrial pollution within Eloor municipal area.

Concept of Sustainability in terms of Industrial Pollution

Sustainable development is people-centered since it seeks to improve the quality of human life, and it is conservation-based as it is constrained by the need to preserve nature's ability to supply resources and life-sustaining services. According to this perspective, sustainable development entails *"increasing the quality of human existence while remaining within the carrying capacity of supporting ecosystems."*(7).
The establishment of a suitable strategic development for industrialization by decision makers, with stakeholder engagement and approval, and implementation at various levels of the system in the industrial region, while balancing the triple line bottom with sustainable guidelines and tools, is what sustainable industrial development is all about. Sustainable industrial development could be defined *as "the industry which meets the needs of the present by taking into account the environmental, social and economic dimensions for suitable development and balancing them without compromising the ability of future generations to meet their own needs"*(7).

The following are the major challenges faced by industrial regions in terms of sustainability globally:

- Waste management and emissions
- Climate disruption
- Toxic Pollution
- Ecosystem degradation
- Resource depletion

- Environmental injustice
- Employment/Purchasing power
- Economic inequity
- Efficient infrastructure
- Land deterioration

Minimizing environmental impact by reducing waste generation, emissions, and environmentally sound management of residual wastes; and minimizing health risks: caused by environmental emissions, as well as the provision of goods and services that support the occurrence of these environmental emissions are all part of the industrial region's sustainability (6).

Study Area

The project's area of study is the Eloor municipal area, an island on the outskirts of Kochi City in Ernakulam district, bordered by two branches of the Periyar River, Kerala's largest river. Eloor Municipal Area is part of the Greater Kochi Area (GKA), which is ranked 24th among the country's severely polluted areas (CPA) (with a CEPI score of 75.08). (2). According to Census 2011, it has a population of 31,468 people and a total area of 14.21 square kilometers. Figure 1. shows the location of study area and nearby local bodies (10).

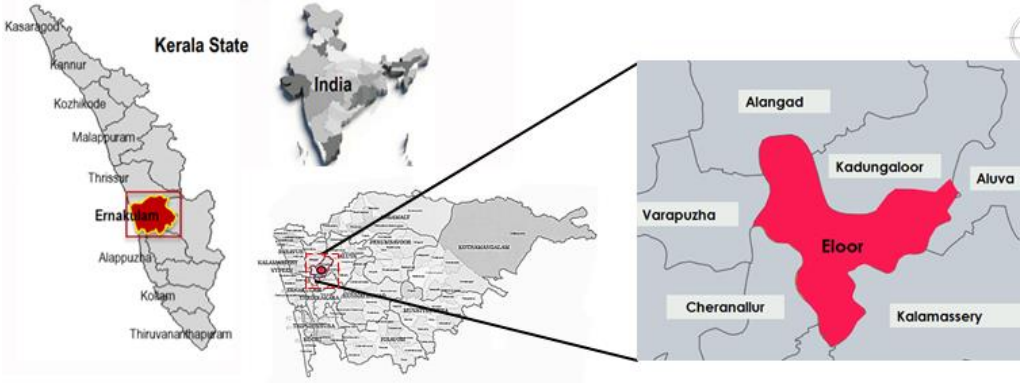

Figure 1. Map showing location of study area and its nearby local bodies

Connectivity

The study region is well connected to major metropolitan areas such as Aluva, Paravur, and other nearby cities, and has excellent transit potential across all modes. The Eloor municipal area is served by National Highway 966A (NH 966A), which runs from Kalamassery to Vallarpadam International Container Transhipment Terminal and junctions with NH544 and NH66 at the Kalamassery and Cheranalloor Junctions. The nearest railway station is Kalamassery, which is 3 kilometres from the Eloor municipal area. Eloor Ferry is located in the municipal area's western section. Mannamthurath and Cheranalloor are the municipality's closest ferry terminals. Cochin International Airport, 14 kilometres from Eloor, is the closest airport to the municipal area. The main port is Cochin, which is roughly 13 kilometres from Eloor municipal area. Figure 2. shows the regional connectivity of the study area.

Figure 2. Map showing connectivity of the study area

Industrialization

Eloor was only known to locals before to industrialisation, and it was completely agrarian and rural. The residents of Eloor created and consumed local products during the pre-industrialisation period. However, the introduction of industries significantly altered Eloor's environment. Eloor's change in the percentage of urban and rural residents was induced by jobs. Individuals from all over the Districts began to move for employment as industries developed, resulting in an increase in Eloor's urban population. The shift in labor from agriculture to industry wreaked on Eloor's agriculture scenario. Following industrialization, there was a rapid decrease in agricultural area and, as a result, a decrease in productivity. The agricultural fields were filled and utilised for the construction of industries, highways, and residential structures, as well as factory dumping yards (4).

Economically, the inhabitants of Eloor benefited greatly from the new types of work options, and their purchasing power increased significantly. Ironically, industrialization has also contributed to the disturbance of Eloor's eco-system, which has been recognized as one of the "toxic hot spots" contaminated with heavy metals and pollution (8). In the absence of sufficient waste treatment facilities, the environment of Eloor - its soil, water, and air - became heavily contaminated by factory discharges/effluents. Unsustainable development in the region has harmed the environment as well as people's health, quality of life, and livelihoods, sparking a wave of anti-industry protests (4).

Land use

The study area has a total land area of 1421 Ha, with residential use accounting for 59.37 percent of the gross land area (70.54 percent of net area). In comparison to the other component local bodies of Kochi City Region, the area under Paddy/Wet land is less. Eloor Municipal area has a net developable area of 1196.07

Ha (excluding paddy, wet land, and water bodies) (5). In comparison to other local bodies in KCR, industrial land use has a significant role in Eloor (16.87 percent), which is prevalent in 6,7,17,29 wards of the study area. The land use map and land use breakup of the study area are shown in Figure 3. and Figure 4. respectively.

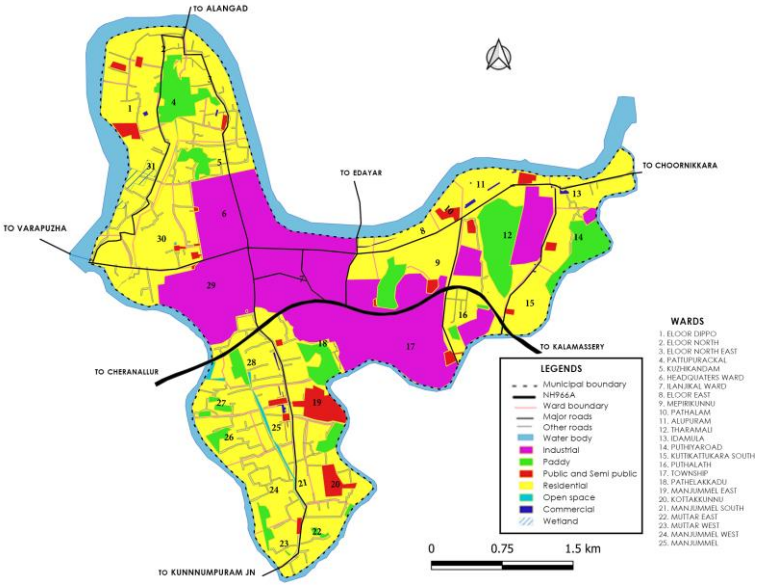

Figure 3. Landuse map of the study area

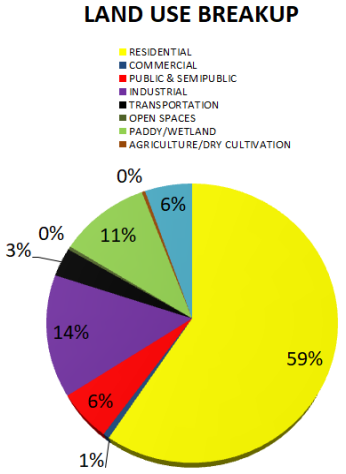

Figure 4. Pie chart showing the land use breakup of the study area

Types of Pollution

The Eloor municipal area is constantly polluted by the industries which accounts to water, air and soil pollution of the region.The region's river water and ground water, as well as the air, are dangerously contaminated. The presence of very hazardous organochlorines and heavy metals pollutes the whole atmosphere. It has been discovered that the metals discovered to be polluting the streams have a wide variety of harmful effects in both terrestrial and aquatic environments.

Water Pollution

Due to industrial fluxes and salinity, the region's ground water is extensively polluted. Excess minerals and other contaminants that impair water quality are indicators of this. The quality of the region's ground water has revealed that the levels of the parameters exceed not only their natural amounts, but also the ISI/KSPCB regulation limits (1).

The distribution of water quality index in the region is shown in Figure 5.

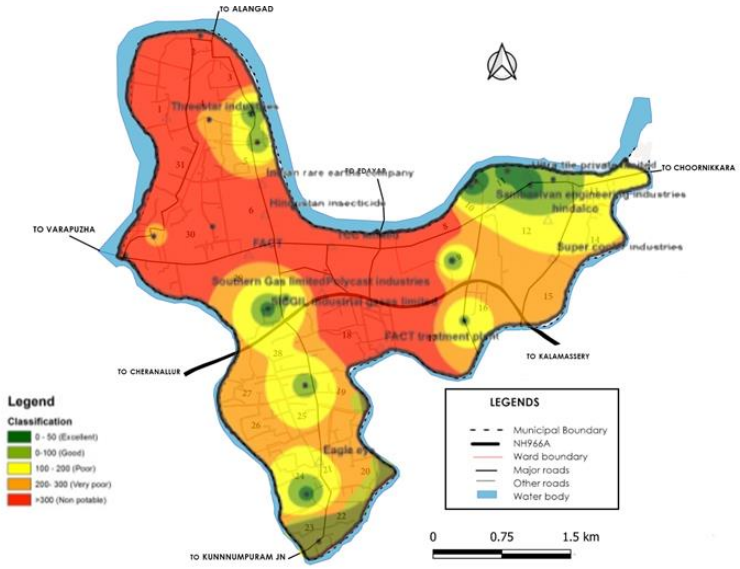

Figure 5. Map showing the distribution of water quality index in the study area(3)

Air Pollution

The presence of highly hazardous organochlorines and heavy metals pollutes the whole atmosphere. The major air quality indicators of concern in this area include SPM, VOC, CO, SO2, NH3, NOx from the Kochi Refinery and other petrochemical and fertilizer industries [10]. The industrial cluster region is experiencing dust pollution as a result of several ongoing construction activities and proposed development projects, notably the Vallarpadam Container Terminal. The data on ambient air quality indicate that sulphur dioxide and nitrogen oxide levels are always below permissible levels. Air emissions range from acid mist to sulphur dioxide, Hydrogen Sulphide, Ammonia and Chlorine gas. The heavy traffic density in the congested roads causes the dust to get scattered and air borne (10). Figure 6. shows the air emissions from industrial areas of Eloor.

Figure 6. Air emissions from the Industries of study area(11)

Land/Soil Pollution

There is significant pollution of soil with DDT, HCH (BHC), Endosulfan, heavy metals, and a wide variety of other dangerous organochlorines owing to the discharge of untreated effluents (4). The polluted paddy fields in the study area are shown below in Figure 7.

Figure7. Polluted paddy fields in the study area

Impacts of Industrial Pollution

The study reveals that industrial pollution in the region affects the sustainability of the surrounding communities and can be classified as Environmental, Health and Socio economic impacts.

Environmental impacts

The region's industrial pollution has degraded the water, air, and land environments. As a result, the following effects have been occurred:

- Loss of biodiversity
- Food insecurity due to crop damage
- Degradation of the landscape/aesthetics pollution of the soil,
- Overflow of waste
- Surface water contamination / deterioration in water quality
- Pollution or depletion of groundwater
- Large-scale disruption of hydrological and geological systems and increase of susceptibility to flood.

The low lying areas which were affected during Kerala Flood 2018 are shown in Figure 8.

Figure 8. Flood prone areas in the study area (8)

Health impacts

Due to the presence of hazardous chemicals in the environment, the majority of people in this region are suffering from significant health issues such as cancer, congenital birth defects, bronchitis, asthma, allergic dermatitis, and stomach ulcers. Many individuals are hesitant to see doctors due to ignorance and a lack of financial resources. According to the survey, the majority of the people do not have health insurance (4).

Socio economic impacts

People have been forced to relocate due to industrial pollution. The study discovered a decrease in population in wards near to industrial areas. Environmental regulations and protection acts are less well-known among the residents of the region. There is a lack of environmental education and awareness among them. It has also resulted in concerns including loss of livelihood, loss of landscape/sense of place, and industry-related protests (8).

SWOC Analysis

From the detailed study of the area, the major strength weakness opportunities and threats can be identified.

Strengths

- The major strength of the study area is its transportation potential and connectivity. The study area is well connected to major urban centers and has a potential for all modes of transportation.
- Water availability from periyar is a major strength for overall growth of the study area.
- Proximity to industrial areas-Edayar, Kalamassery and Aluva can influence the future industrial growth of the area

Weaknesses

- The existing industrial zone has no considerable amount of green areas. There is no proper buffering between industrial and residential land use.
- Contamination of creeks and canals due to improper drainage systems and effluents from factories.
- Out migration of people due to effects of industrial pollution
- Decrease in agriculture land use and Loss of livelihood for fishing and agriculture dependent population
- According to health surveys, the majority of households are suffering from significant health issues like as cancer, congenital birth defects, bronchitis, asthma, allergic dermatitis, and stomach ulcers as a result of industrial pollution. Majority of the households of affected area are unaware of health insurance schemes

- The factories discharge partially treated effluents directly to Periyar River.
- Land environment are polluted and are contaminated with the presence of heavy metals and chemicals

Figure 9. shows the contaminated canals and drainage lines in the study area

Figure 9. Contaminated canals and drainage lines in SC-ST colonies

Opportunities

- The proposed industrial corridor through the study area can influence the area's growth and importance.
- Eloor municipal area can be a major node of industrial activities in future.
- The proposed inland water transport system can boost up the water transportation potential of the study area.
- According to the development plan of KCR 2031, higher order industrial facilities are proposed in the study area. Road widening proposals are also included in the proposed development plan.

Challenges

- The increase of industrial activities itself can be a challenge for liveability of future population.
- Emergency evacuation or rehabilitation is not possible in case of chemical disasters in factories as it lacks disaster management plan. It can badly affect the surrounding settlements' sustainability
- Disappearance of green spaces can affect the ecosystem of the study area.

Strategies for improving the Sustainability of the region

From the detailed study and SWOC analysis of the area, it is important to protect the components of Physical, Socio-economic and natural environment in order to improve the sustainability of the region. Physical environment includes physical characteristics of the area like demography, land use, transportation and Socio economic environment which includes the factors like Employment, Health etc. and Natural environment which includes the water, air and land environment of the study area.
For the sustainable development of the region, the vision statement has been formulated as:
"Strengthen the sustainability of Eloor industrial region by protecting the physical, socio-economic and natural environment from the impact of industrial pollution and increase healthy living."

The following are the goals to focus in order to achieve the vision of the project:

- To improve the quality of water, air and land environment.
- To protect public health that ensure safe and liveable communities
- Awareness creation and capacity building of the communities
- To promote sustainable industrial development by reducing the impact of industries to residential areas

Phasing of Strategies

The strategies can be categorized into short term, mid-term and long term with respect to the time frame.

Short Term (Phase 1)

1) Revitalization of contaminated creeks and canals

It is critical to rejuvenate polluted water bodies and streams that pose a hazard to residential areas and have an impact on the quality of water, air, and land as an immediate response to the impacts of industrial pollution.

2) Installation of Automated water & air quality station in vulnerable locations for monitoring pollutants using a variety of analyzers.

Continuous Ambient Air Quality or Water Quality Monitoring Stations (CAAQMS) may monitor pollutants using a range of analyzers, reducing the possibility of human error, produce data at minute intervals, and transfer the data to a central location. Currently, there is just one continuous ambient air quality monitoring station (kept by FACT) at Eloor. By placing these stations in the most polluted areas, data on pollutants and their intensity can be continuously recorded and evaluated.

3) Improvement of health care facilities in the region.

A primary health center is now located in Ward 31 in the Eloor municipal area. It lacks inpatient facilities and other services due to a lack of resources. Private hospitals are being used by 53% of the population. The Public Health Centre (PHC) would be transformed into a Community Health Centre (CHC), complete with inpatient treatment and other essential services. Regular medical camps for early diagnosis/detection of illnesses must be organized under the supervision of the local self-government, and people must be provided health cards. In addition, frequent studies on occupational health concerns among workers in Eloor's industries may be undertaken by a competent organization, and quarterly health and hygiene awareness camps must be conducted by the Public Health Centre.

Mid-term (phase 2)

4) Proposal for Common effluent treatment plant (CETP) at Eloor industrial area

CETPs are utilized to get beyond the limitations of wastewater treatment in specific sectors. CETPs have the potential to reduce the cost of treating mixed wastewater from diverse sectors while also facilitating improved compliance and monitoring with regulations. A common wastewater treatment system is a potential option for achieving the objective of "zero effluent discharge to the Periyar River." For the effluent to be received at CETP, a specialized closed circuit pipeline network system will be installed.

- Improvement of infrastructure facilities in Industrial areas.

- Identification and implementation of waste minimization and waste exchange options.

Long term (phase 3)

5) Green belt development & Massive planation of trees as buffer zones.

The prime objective of the green belt is to act as a buffer or barrier between pollution sources and the surrounding areas. Apart from increasing the region's visual qualities, the green belt serves to absorb fugitive pollutants and reduce noise. To reduce air pollution and increase the biodiversity condition of the study region, a greenbelt will be constructed using appropriate plant species as indicated by CPCB recommendations.

6) Zero discharge of effluents to River periyar

To eliminate sewage leakage in pipes and seepage in unlined channels, as well as sewage mixing with groundwater, broken pipelines and sewer drain lining must be replaced. To improve groundwater quality and protect people and animals from the hazards of groundwater contamination, it is necessary to decrease pollution from industrial effluents by implementing strict laws.

• Preventing the construction of waste-producing activities along the river's banks, such as industries, slaughterhouses, marketplaces, transportation and car centers, and so on.
• Identifying waste reduction and waste exchange possibilities
• All sewage canals leading to the river must be closed.

7) Chemical disaster management plan

To protect the local people from the potentially harmful health effects of a toxic release, the district level disaster management plan, particularly for Chemical Disaster Management, should be created and updated on a regular basis and kept available for action as needed. Furthermore, industries should take the lead in educating the public about disaster management practices ahead of time in order to minimize mass casualties. Figure 10. shows the chemical disaster which occurred during 2020 in nearby industrial estate of the study area.

Figure 10. Chemical disaster occurred at Neighbouring estate (11)

The sustainability of the study area can be enhanced by implementing the major strategies and proposals. Table 1. shows the major strategies and sustainability issues which are addressed through it.

Table 1. Major strategies and the sustainability issues addressed by them

Major Strategies	Sustainability Issues Addressed
Revitalization of contaminated creeks and canals as a result of industrial pollution.	• Water pollution • Livelihood problems of water dependent population(eg: Prawn cultivators) • Deterioration of water quality • Impacts on aquatic life such as fish kills. etc.
Installation of Automated water & air quality station in vulnerable locations for monitoring pollutants using a variety of analyzers.	• Air pollution • Air borne diseases in communities
Improvement of health care facilities, Arrangement of health camps, Introduction of health insurance packages to affected areas.	• Issues related to Health, Quality of life, Socio economic stability etc.
Replacement of broken pipelines and lining of sewer drains Identification and implementation of waste minimization and waste exchange options.	• Surface water contamination / deterioration in water quality • Overflow of waste • Soil/Land pollution
Up gradation of infrastructure facilities in Industrial areas. Proposal for Common effluent treatment plant (CETP) at Eloor industrial area.	• Unsustainable industrialization • GHG emissions • Atmospheric pollution etc.
Green belt development & Massive planation of trees as buffer zones.	• Loss of biodiversity • Degradation of the landscape/aesthetics • Air pollution, Soil erosion etc.
Chemical disaster management plan	• Adverse health impact on communities • Chemical disasters, Flood susceptibility etc.

Conclusion

The study is on the impact of industrial pollution in the Eloor municipal area on the region's sustainability. Eloor's industrialization has both positive and negative consequences for society. Eloor developed as a major industrial power, and the pre-industrial (feudal) society gave place to a new social culture. Eloor residents profited substantially economically from the new sorts of employment opportunities, and their purchasing power continued to rise. Strangely, Eloor's eco-system has been identified as one of the "toxic hot spots" plagued with heavy metals and toxins as a result of industrialization. Due to a lack of suitable waste treatment facilities, Eloor's environment - its soil, water, and air - became considerably contaminated by industrial discharges/effluents. The region's river water, ground water, and air are all severely contaminated. The presence of very hazardous organochlorines and heavy metals pollutes the ecosystem as a whole. The research looked at the consequences of industrial pollution on the environment, human health, and the economy in the region under consideration. These effects, according to the study, are linked to the quality of life in the neighbouring areas. The physical, social, and ecological aspects of the region should be addressed in order to improve the sustainability of the study area. It includes a commitment to and action on reducing the environmental impact of processes that use resources more efficiently and optimize the productive use of natural resources; minimizing environmental impact by reducing waste generation, emissions, and health risks caused by environmental emissions. Thus, improving the quality of life and the surrounding environment might increase a region's sustainability.

Acknowledgments

I express my deep gratitude to my guide Prof. Bindu CA for her valuable suggestions and for guiding me in the course of the research. I would also like to thank all the authors of the referred papers, and all who have contributed in conducting this study.

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