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RESEARCH ARTICLE

Design of strategies for an efficient and applicative transition from the linear economy to the circular economy, Colombia case

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Abstract
The process of transition from linear economy to the circular economy has shown progress in other countries thanks to the strategies implemented, by analyzing these from the perspective of some authors, it was possible to identify which ones can be replicated in the country. The approach of this article is qualitative of a proactive documentary type with an inductive method, the sources were secondary, from databases such as Dialnet, Scielo, Academic Google, repository of universities, books, foundation reports and DANE reports, also information was obtained from a primary source through a dialogue whit recyclers and owners of warehouses in the village of La Playa and Barranquilla. Through the sources, essential strategies for sustainable development in Colombia were analyzed, such as: pedagogical strategies focused on changing the behavior of the various sectors of the community through educational campaigns, technological innovation strategies that allow the development of consumer goods that generate the least environmental impact, and social strategies. It was concluded that eco-design, the implementation of innovative technology and access to loans for circular activities are essential for the development of the model, in addition, successful experiences of developed countries in term of C.E can be replicated since they offer the opportunity to improved through pedagogical technological and social strategies.

Keywords: Circular economy; recycling; eco-design; sustainable development; waste

Introduction

The interest in adopting the circular economy has increased in recent years taking into account that in addition to being considered as an alternative to change the linear economy model, "many companies have also begun to realize that the linear system increases their exposure to risks, especially the increase in the price of resources and interruptions in their supply. " (Ellen MacArthur Foundation, 2014, p.02). As not all resources in nature are renewable, companies are forced to pay more for their raw material to avoid stopping their production. (Sandoval et al., (2017) affirm that what is involved is to close the cycles of energy, of materials it is not about going against economic growth, but that the resources we have have an intensive use instead of increasing their exploitation ". A circular economy contributes to at least 12 of the 17 goals outlined in the UN's 2030 Agenda for Sustainable Development." (Ellen MacArthur Foundation, 2019, p 19). Chaves, R. & Monzón, J.L. (2018) conceive that the circular paradigm is in the current production system an innovative change, since the idea of regeneration is present in each phase of the production process. (p. 34). "In EC, one of the goals is to increase product life, produce goods with long life cycles, and focus on services rather than products." (EU-LAC Foundation, 2018, p 8). Brook. (2018). Expresses that, in Europe and Asia, the incorporation of this economic paradigm is promoted through the implementation of pedagogical, technological and social strategies. Sweden, in 1997 outlined its current energy policy, whose motto was the transition to an ecologically sustainable society, this is evidenced in research such as (Moreno et al., 2022; Moreno Rocha et al., 2022). Fulfilling this goal, the European country opted for recycling, its population is characterized by recycling 99% of its organic waste and 88% of inorganic waste and this is how it now produces energy through the "From waste to energy" program. The initiative has proved so effective that Sweden now imports tons of waste from other countries such as Italy and the United Kingdom to supply the 32 energy centers it now owns.
In the study Advances and challenges for inclusive recycling: Evaluation of 12 cities in Latin America and the Caribbean developed by The Economist Intelligence Unit. (2017) Brazil is recognized as one of the pioneers of inclusive recycling in Latin America and the Caribbean, also highlighting that in BuenosAires recycling becomes

an activity co-managed by the State and cooperatives, with a joint social responsibility, in the Colombian case in Bogotá the recyclers become visible and are recognized as providers of the public cleaning service, and are therefore entitled to remuneration. (p. 22)

In Colombia, Resolution No. 1407 of July 26, 2018 aims to regulate the environmental management of packaging waste and packaging of paper, cardboard, plastic, glass and metal."

Although materials are used through recycling, the disproportionate increase in plastic during the COVID-19 pandemic since 2020 is worrying since not being able to recycle all single-use plastic would increase environmental pollution (UN News, 2021).

The chemist-ecologist Michael Braungart and the American landscape architect William McDonough, consider that currently there is no recycling but an undercycling because the raw material is losing value until the usefulness of the material reaches its lowest level, just as in recycling, reduction and reuse do not meet 100% with the objective set by the circular economy (McDonough and Braungart, 2005).

Therefore, the objective is to analyze pedagogical, technological and social strategies of circular economy as a factor of sustainable development from the perspective of studies of authors that can be replicated in Colombia.

Methodology

The focus of this article is qualitative of a propositive documentary type with an inductive method, an analysis of scientific literature was carried out, databases such as Dialnet, SciELO, Google Scholar, repository of universities, books, reports of foundations and reports of DANE, information was also obtained from primary source through a dialogue with recyclers and owners of deposits of the corregimiento la playa and Barranquilla.

Development

For the Hellen Mac Arthur Foundation, (2014). The Circular Economy differs from the mere management of waste and recycling in that theproducts designed and optimized can be reused their components, in this way large amounts of energy and labor are not lost as it happens in recycling, this is what defines the Circular Economy. (p. 4). The reason why it is considered that recycling does not fully meet the requirements of the circular economy according to McDonough and Braungart (2005) is because raw materials are not designed for this purpose, for this reason, although once their useful life cycle is finished they are transformed into new materials, the result is a low quality product. When plastics other than those used in soft drink or water bottles are recycled, they are mixed with different plastics to produce a lower quality hybrid, which ismolded amorphously and cheaply.

In Colombia, DANE in its First Circular Economy Report of 2020 defines the

circular economy such as:

> "a system of production and consumption that promotes efficiency in the use of materials, water and energy; taking into account the resilience of ecosystems and the circular use of material flows through the implementation of technological innovations, alliances and collaborations between actors, and the promotion of business models that respond to the fundamentals of sustainable development". Pag (7)

Although the circular economy is frequently associated with recycling and perhaps the power of this in being transformed into energy as evidenced in research such as (Manuel et al., 2022), this is not the only way to contribute to the Sustainable Development Goals (SDGs), other ways to contribute to these objectives is the creation of companies whose purpose is the EC, To achieve this end they focus on the design of innovative products that can be reused, repaired, remanufactured or recycled, this strategy allows them to be more competitive by reducing investment in virgin raw materials.

The DANE in its first circular economy report published on August 5, 2020, marks the starting point of the SIEC Circular Economy Information System that will integrate technical and statistical information to generate new knowledge and guide the execution of the Pact for Sustainability, and the public policies that are formulated in this regard.

This report presents indicators of statistical information that are classified into four components that allow analyzing some topics of interest to the Colombian case such as: extraction of environmental assets, production of goods and services, consumption and use, closure and optimization in the life cycles of materials and products. In the Second Report published on December 11, 2020, it presents 23 indicators of available statistical information and the classification of the components remain the same as the first report.

In the third circular economy report published on July 28, 2021 , there are four new components, these are: demand for environmental assets and ecosystem services, conservation or loss of value of materials in the productive system, pressure on ecosystems due to the disposal of waste and the fourth is factors that facilitate the Circular Economy. Without departing from the purpose of the first two reports, this is the result of the statistical articulation undertaken by DANE within its technical directions, but also in the context of the National Statistical System SEN.

In the Fourth Report published on December 2, 2021, the Circular Economy indicators were categorized into the following four components: Demand for environmental assets and ecosystem services, conservation or loss of value of materials in the productive system, pressure on ecosystems due to the disposal of waste and Factors that

facilitate the Circular Economy. This report includes for the first time information about the indicators of area modified by type of forest cover, sustainable extraction, extraction and use of timber resources, in natural forest, Pressure for fishing and Average size of catch and distribution by size.

The fifth circular economy report published on June 23, 2022 maintains the following components: Demand for environmental assets and ecosystem services, conservation or loss of value of materials in the productive system, pressure on ecosystems for the disposal of waste.

In the first report, the indicator Percentage of households that make separation in the source of waste expresses that in 2018 39.9% of households (6.2 million) of a total of 15.5 million, made separation at the source of some type of waste and households by departments that classified waste in a higher percentage were: Bogotá D.C, Antioquia, Caldas, Santander, Cundinamarca, Boyacá, Casanare, Valle del Cauca, Putumayo, Huila and Nariño, while in the fourth report it appears that between 2018 and 2020 the highest levels of waste classification according to the departments is headed by Bogotá D.C. and in the departments of Santander, Cundinamarca, Boyacá, Putumayo, Antioquia and Cauca.

Table 1. Components that group the Circular Economy indicators

First report August 5, 2020	**Second report December 11, 2020**	**Third report July 28, 2021**	**Fourth report December 2, 2021**	**Fifth report June 23, 2022**
1.Extraction of environmental assets. **2. Production of goods and services.** **3. Consumption and use.** **4. Closure and optimization in the life cycles of materials and products.**	1. Extraction of environmental assets. 2. Production of goods and services. 3. Consumption and use. 4. Closure and optimization in the life cycles of materials and products.	1.Demand for environmental assets and ecosystem services. 2. Conservation or loss of value of materials in the production system. 3.Pressure on ecosystems for waste disposal. 4. Factors that facilitate the Circular Economy.	1. Demand for environmental assets and ecosystem services. 2. Conservation or loss of value of materials in the production system. 3. Pressure on ecosystems for waste disposal. 4. Factors that facilitate the Circular Economy.	1.Demand for environmental assets and ecosystem services. 2.Conservation or loss of value of materials in the production system. 3.Pressure on ecosystems for waste disposal.

The second report of the DANE of 2020 maintains the logic of output or product, in this one addresses among other issues the form of disposal of waste from households in the country, it is mentioned that in the urban area the type of fuel that is used in greater proportion is natural gas, while in rural areas it is propane gas and firewood or wood.

With regard to the collection or disposal of garbage, the second report reports that in 2019 81.2% of a total of 15,999 households had a garbage collection service through the cleaning company, while 12.6% of households burned garbage and 6.2% disposed of garbage by another means. In 2018, the number of households that had the garbage collection service was 0.51% lower than in 2019 and the percentage of households that burn garbage remained the same. Page 7

In the fourth report regarding the way households dispose of their waste, a difference in the data can be observed when compared with those of the second report. In 2018 80.7% of households had a toilet service, in 2019 81.2% of households had a garbage collection service through the cleaning company and between 2019 and 2020 the fourth report reports an increase of 0.6% in households with toilet service, burning as a way to eliminate waste in 2018 and 2019 was 12.6 and between 2019 and 2020 it was 11.8% presenting a decrease in burning by 0.8%.

Table 2. Percentage of households by form of waste disposal National total 2018 - 2019

Year	It is collected by the toilet services	They burn it	Another way
2018	80,7%	12,6%	6,7%
2019	81,2%	12,6%	6,2%
2019-2020	81,8%	11,8%	

In the fifth circular economy report, the indicator percentage share of the consumption of energy products of households that is part of the component Demand for environmental assets and ecosystem services, presents the participation of the consumption of each energy product within the total consumption of energy by households, in this you can see how the demand for each type of product increases or decreases. Page 11.

Table 3. Percentage share of energy product consumption in total household energy consumption. Total, national 2016-2020

	Liquefied petroleum gas (GUP)	Natural gas (distributed)	Firewood	Motor Gasoline	Electricity
2016	5,5´0%	11,3%	21,3%	28,5%	33,3%
2017	6,3%	11,5%	18,7%	30,9%	32,6%
2018	5,0%	13,4%	20,5%	24,4%	36,7%
2019	5,7%	13,0%	18,3%	26,0%	37,0%
2020	7,4%	14,4%	18,8%	20,3%	39,1%

Results

Strategies

Working ondesign has become a strategy of some Asian and European countries such as Japan, South Korea, Germany, Norway, Spain, Italy and Switzerland among others, in order to close the cycles of resources and be reused all its components.

With respect to private companies, they must establish as strategies the accompaniment of campaigns that promote the importance of the adoption of EC in economic, social and environmental development. To achieve this end, the training of committed leaders convinced of the benefits of the circular model is essential. Kowszyk and Maher in their case study for the EU-LAC Foundation (2018) highlights the importance of dreamy, idealistic and courageous leadership at the head of companies, an example of the importance of assuming this attitude is presented by this study in the company Neptuno Pumps of Chile where its Executive Director Petar Ostojic decided to act as a promoter of EC in the media of Chile and Latin America to raise awareness about the Importance of this business model, also as a strategy went to the use of social networks, the organization of talks and presentations in companies, universities and other institutions, this work that was of personal initiative led him to receive awards and recognition for his achievements in the field of EC by Latin American governments and the World Economic Forum and UN agencies. In Colombia, Resolution No. 1407 of July 26, 2018 aims to regulate the environmental management of packaging waste and packaging of paper, cardboard, plastic, glass and metal.

In chapter 3 article 11 of said resolution, are among other obligations: Promote the incorporation of circular economy guidelines, in the prioritization of alternatives for the use of packaging waste, and support the manufacturer in innovation and ecodesign for the manufacture of containers and packaging with sustainability characteristics.

Chapter 2 Article 9 establishes quantitative targets for producers where "Producers shall meet the target of using packaging waste with respect to the total weight of packaging placed by them on the market in the base year," below are the percentages set out in Table I of this Resolution."

Table 4. Quantitative targets for producers

Evaluation period Year	Annual increase (% meta)	Goal of use of packaging waste (%)
2021	10%	10
2022	2%	12
2023	2%	14
2024	2%	16
2025	2%	18
2026	2%	20
2027	2%	22
2028	2%	24
2029	3%	27
2030	3%	30

On December 24, 2020, the Ministry of Environment and Sustainable Development issued Resolution 1342 of 2020, modifying Resolution 1407 of 2018. Among the modifications are that of Paragraph 1 of Article 2 of Resolution 1407 to indicate that, within the exclusions of this regulation, the packaging and containers of drugs and medicines in general are included, eliminating the reference to primary packaging and containers.

Article 8 of Resolution 1407 is modified by establishing that existing producers as of December 31, 2018, must

submit the Environmental Waste Management Plan no later than January 31, 2021, thus extending the period that was indicated above and that expired on December 31, 2020 for existing producers as of December 31, 2018, Article 16 of Resolution 1407 was modified, in this it is established that natural or legal persons who consume or use goods or services, as the last link in the marketing chain must: - Carry out a correct separation at the source of packaging waste and deliver the separated waste at collection points, requirements are established for producers with returnable packaging systems, with the aim of establishing the returnability efficiency indicator and alternatives to obtain a returnability efficiency certification are included.

In order for the process of change not to stagnate, pedagogical, technological and social strategies that can be replicated and that are aimed at empowering CD must always be present.

Pedagogical Strategies

Having clarity about what the circular economy is allows company directors to transmit the concept of EC to their employees and other actors related to the company, to identify which issues they can lead with their experience and knowledge and in which they can benefit from learning from others, all the challenges they face on the road to greater circularity can be solved (EU-LAC Foundation 2018).

Sáez and Urdaneta, (2014) suggest in their conclusion that to achieve improvements in solid waste management in Latin America and the Caribbean requires will on the part of governments, strong investments and continuous education of citizens on the issue of waste use.

The organization of conferences and activities in companies, microenterprises and educational institutions accompanied by information on the proper management of solid waste and the contribution that these can generate if they are commercialized, will allow to demonstrate the changes in society. The relevance and applicability of modules to develop recycling projects in Educational Institutions allows young people to multiply knowledge in their community. From the perspective of Romero, (2017), schools are the ones that allow pilot tests, because there is a certain level of plurality depending on their type and location, in addition, the actors involved are repeaters of knowledge within their environment regarding Solid Waste Management.

To reduce the strong negative impact generated by the textile industry on the environment, it becomes pertinent that the consumer is aware of the final destination of their garments, Peña A (2019) recommends that the will of the consumer is important and that through educational campaigns about raising awareness about the large number of impacts generated by the textile industry, by the abandonment of a garment, its decomposition time, the amount of dyes and microplastics generated as a result of its decomposition.

During the I International Congress of Sustainability organized by Knauf in October 2018 in Madrid, the ABC live interviewed the architect Walter Stahel he commented that "we always forget that there is a renewable resource: work, human labor. We must produce a better human resource, because if we do not use this resource, we will not move forward. You have to focus on people, on training"

The COTEC Foundation for Innovation, in its 2017 report "Situation and evolution of the circular economy in Spain", is aware of the lack of information and data that allow actions to be taken in search of the adoption of the circular economy effectively.

In Colombia as in any part of the world, the process of transition from linear to circular is only possible with the presence of leaders who know and recognize that its implementation generates great benefits and that, to achieve results, the first thing to do is to change the mentality of those who run the companies and that of the citizens of all social strata. For Soria, (2016) educational strategies are those that allow generating environmental awareness and managing the characterization of waste, in this way the generation of economic income for people dedicated to recycling can be improved by applying a more comprehensive recycling.

On June 14, 2019 at the Chamber of Commerce of Medellín, President Duque officially launched the national economy strategy, through which it is intended that the country become one of the three most competitive economies in Latin America by 2030. To achieve this goal, he emphasized the need to reach the awareness of Colombians about the good management of garbage, efficient handling of materials, water and energy, and also encouraged producers, suppliers, consumers and other actors in the productive chain to develop business models that incorporate waste management, efficient management of materials and change in the lifestyles of citizens.

Technological Innovation Strategy

To achieve the transition process towards the circular economy, it is necessary to innovate in new technologies, processes, services and business models, and to make consumers aware of the importance of changing their behaviors COTEC, (2017).

Currently, the vast majority of companies only have machines that fit the linear economic model and designers focused on products that have as characteristics to become garbage in the literal sense of the word or in the best case be suitable to be recycled losing their quality in each process until losing their value completely.

To be able to adopt the EC it is essential to have eco designers who elaborate products that from the moment

they begin to create take into account that these should not lose value, but at the same time it is necessary to have machines capable of disassembling the product to consider which parts can be remanufactured. If it is a recycling company, you must have machines capable of identifying and separating each of the materials that compose them.

It is important that once the useful life of a product is over, they can decompose in the soil and provide their nutrients to the soil or are food for plants and animals, otherwise they are useful to be reincorporated back into industrial cycles to provide quality raw materials, (McDonough and Braungart 2005)

The ABC of the orange economy defines it as a tool for cultural, social and economic development that differs from other economies by the fact that it is based on the creation, production and distribution of goods and services whose cultural and creative content can be protected by intellectual property rights, therefore if the orange economy is considered as a tool of economic development, this can support technological creativity so that companies are competitive and can consolidate with innovative technology, therefore it is pertinent that projects supported through the orange economy focus on innovative technology at the service of the circular economy.

The Development Bank of Latin America CAF (2018), Development of a study that allows to know the contribution of innovative technology in the field of solid waste in countries of Europe, Asia and other countries. The result of this studyor shows the panorama of the state of consciousness of other countries with respect to the circular economy and what is proposed is that a deep evaluation of the possibility of replicability be made taking into account that it adapts to the Colombian context. What the report shows is that there are systems that recognize the people who recycle, the type of waste, systems that warn when the containers are filled and these automatically compact the garbage, specialized systems for people with disabilities, machines that give money in exchange for materials that are recycled and luminous screens that inform the user about the classification of waste.

Proposed social strategy

The offer of products that have a programmed useful life is what is known as planned obsolescence, this generates in many Colombian households negative impacts on their economy making evident the economic interest on the social interest, the absence of social contribution by these manufacturers is in Europe and the same should be in Colombia a subject of interest of different social groups.

In Europe, the Spanish Technical Institute of Cleaning (2017), states that the denunciation of different social groups has caused the fight against obsolescence to be incorporated into its agenda, issues such as increasing the coverage of guarantees, the establishment of minimum useful lives, or information to the consumer about the useful life of each product are supported by the new legislation as lines of fight against obsolescence.

For most households electronic devices and appliances more than a luxury has become a necessity, therefore, the absence of any of these devices affects the quality of life of many families, being so, the repair positively impacts the economy due to the decrease in costs, therefore, being able to access these is facilitated and has an impact on the social aspect. The contribution of the repair and reconditioning cannot be ignored, however, it must be required that the repaired items have a certification and a logo that identifies them, and that for this reason their cost is lower without this indicating lower quality.

With regard to recycling, it must be taken into account that the organization of this sector of society dedicated to collection is in process, employers can adopt some workers of this trade who work in their environment and provide them with endowment every six months and make them aware of how important their work is for society, the environment and the economy of the country, when their work is dignified, will not feel like a relegated social class of little value, they can even become multipliers in their area of work of the benefits of a correct classification of solid waste.

For the COTEC Foundation (2017), the transition from the linear to the circular economic model can create numerous jobs and promote socio-economic growth at the local level and strengthen social cohesion and integration. By investing less in raw materials, workers' working conditions can be improved.

Discussion

The circular economy as an economic model must be recognized for its social, economic and environmental contribution, therefore companies must adopt as a strategy a leadership focused on the sustainability of the EC, although it is true that the government must do its part, that is, create policies that support the development of the circular economy, companies must concentrate on strategies that allow the transition from the linear model to the circular from their economic activity, the results of these efforts will only be fruitful if there is a reciprocal relationship that feeds both sectors; therefore, the strategies implemented in the public sector should not only have regulations as a preference, but these should be aimed at facilitating access to financial support and financing of projects focused on the creation of innovative technology useful for companies in all sectors including those responsible for solid waste collection. (discussion)

Taking into account that the deterioration of the planet is not diminisheddue to the fact that there are still inappropriate practices in human beings and an economic model that prevails despite the efforts, it becomes mandatory that at the local and global level the strategies aimed at making the circular economy model mandatory and not remain only in the discourse

Table 5. Types of Strategies to Empower E.C.

Pedagogic	Technological	Social
• **The clarity of the circular economy allows company directors to transmit the concept of EC to their employees and other actors related to the company, (EU-LAC Foundation 2018).** • **Strong investments and continuous education of citizens on the issue of the use of waste. Sáez and Urdaneta, (2014)** • **The schools allow pilot tests, in addition, the actors involved are repeaters of the knowledge within their environment regarding Solid Waste Management. Romero, (2017).** • **raise consumer awareness about the large number of impacts generated by the textile industry, by the abandonment of a garment, its decomposition time, the amount of dyes and microplastics generated as a result of its Decomposition. Peña A (2019)**	• Iinnovate in new technologies, processes, services and business models COTEC, (2017).. • Designmachines to make it easier to disassemble and separate each of the parts and materials that make up a product to be reused, remanufactured or recycled • Support of the orange economy to the circular economy through projects that focus on innovative technology. • There are systems that recognize the people who recycle, the type of waste, systems that warn when the containers are filled and these automatically compact the garbage, specialized systems for people with disabilities, machines that give money in exchange for materials that are recycled and luminous screens that inform the user about the classification of waste. CAF (2018)	• The fight against obsolescence, issues such as increasing the coverage of guarantees, the establishment of minimum useful lives, or informing the consumer about the shelf life of each product are supported by the new legislation as lines of fight against obsolescence. express Spanish Technical Institute of Cleaning (2017), • Require repaired and refurbished items, a certification and a logo that identifies them, and that for this reason their cost is lower without this indicating lower quality. • Educational strategies and waste characterization improve the generation of economic income for people dedicated to recycling by applying a more comprehensive recycling. Soria, (2016) • We must produce a better human resource, because if we do not use this resource, we will not move forward. You have to focus on people, on training" Walter Stahel. • Investing less in raw materials improves workers' working conditions.

Colombia is one of the leading countries in the region that is concerned with showing and promoting an interest for the transition to the circular economy, however, there are different limitations, currently both consumers and companies maintain a relationship of consumption and production focused on the Linear Economy model (produce, consume and discard), privileging factors such as price over quality and useful life of products, (Castle 2018).

It must be recognized that in Colombia people are not yet prepared for certain behaviors driven by CD and their absence can be considered as an obstacle that slows down the transition from the linear to the circular. In Europe there are businesses dedicated to the purchase and sale of second-hand clothes, however, the pride of the vast majority of Colombians is to buy an item made supposedly with virgin raw material since they consider it important to be the first owner and that will guarantee the durability of the article unlike a remanufactured or second-hand product.

Although the circular economy is often associated with recycling, this is not the only way to contribute to the Sustainable Development Goals (SDGs), other ways to contribute to these objectives is the creation of companies whose purpose is the EC, to achieve this end companies must focus on the design of innovative products that can be reused, Repaired, remanufactured or recycled, these strategies allow them to be more competitive by reducing investment in virgin raw materials.

Although the design strategy contributes indisputably from the economic and environmental, Ramos (2019) highlights that by proposing the elaboration of tableware from banana leaves as an alternative to plastic sheets, it is much easier to adopt the circular model when new products are produced because existing ones such as plastic tableware make it difficult to change. "Consumer demand is a crucial component to the success of product design strategies and at any given time can become a barrier to design strategies for EC." (Re yes Forero, I. A. 2021, p 68).

Although the circular economy model has been globally accepted as the appropriate economic model to achieve the fulfillment of the 2030 agenda for sustainable development adopted by the UN General Assembly, this implies that in the transition process the way of producing and a global

awareness of environmental damage must be changed, social and economic generated by the old model of linear economy, it is precisely in these aspects where the different sectors of society must have a clear knowledge, it is well known that many entrepreneurs do not dare to make the leap to have their companies organized with the old form of linear production, change implies investment, time and pedagogy to raise awareness among its managers and staff in general.

If it is a question of achieving the goal that by 2030 Colombia will be among the top three most competitive economies in Latin America, we must not lose sight of the situation that collectors or recyclers are going through.

It is said that cardboard among solid waste is one of the most important for its contribution to the environment, however, this is only the opinion of those who do not exercise this activity and are unaware of the social problems that recyclers or recuperators go through, they ensure that there is no collaboration of society in general with respect to the final disposal of cardboard and other waste, from the economic some say that the collection of cardboard is not profitable due to its volume and its low price, to this is added that there are seasons that greatly lower the value and the response with which they find is that they are not buying.

With regard to deposits, little infrastructure and little technology can be appreciated, however, recycling is still the solution of many desperate unemployed who seek sustenance in this way. Although recycling and reuse are activities that man has practiced since he lives in community, its objective was not to reduce the deterioration of the environment, the reason was and is to survive, to be able to satisfybasic needs.

Taking into account the above, Colombia like other countries is aware that the reduction of pollution generated by solid waste, especially single-use plastics, is one of the great environmental challenges that is intended to be solved with the implementation of the circular economy model, however, with the appearance of COVID-19 these have become a safe protection option worldwide for the security they provide and their low cost. Personal protective equipment such as masks, plastic packaging and other sanitary waste generated for protection reasons, require measures to be taken with respect to collection management practices in order to positively impact health and the environment.

According to Plastics Technology Mexico (2020) in its article Reflections on COVID-19 and residual plastics written by chemical engineer Adrián Méndez Prieto, it is recognized that, although before the pandemic single-use plastics were strongly pointed out, the health sector and governments found the solution to reduce infections and deaths in single-use plastics used in personal protective equipment (PPE) for being reliable and accessible.

UN Environment Executive Director Erik Solheim in the foreword to the UN report SINGLE-USE PLASTICS: A Roadmap for Sustainability (2018), states that plastic is not the problem, the responsibility for what is done with it is ours in terms of how to use it, plastic has facilitated the expansion of solar panels, clean energy from turbines, food storage and in the health sector the use of plastic has saved many lives.

The United Nations reports in UN news Global Look Human Stories of March 30, 2021 that the use of plastic during the COVID-19 pandemic affects the most vulnerable because the disproportionate increase in plastic from 2020 to date is worrying since not being able to be recycled all single-use plastic would increase environmental pollution. According to the United Nations, more than 70% of this plastic will end up in the ocean and landfills, and up to 12% will be burned.

It should not be overlooked that companies dedicated to the manufacture of plastics prioritize the cost of the raw material, therefore, if oil prices are low, virgin resins end up being preferred because they are of lower value with respect to recycled ones. Thus, plastic pollution increases due to the new incursion of new packaging and articles made with virgin resins, in this situation it seems that efforts aimed at protecting the environment and empowering the circular economic model were at a slower pace than environmental deterioration.

With the presence of the pandemic, the little preparation in which the waste recovery system is found in health services, restaurants and other places that depend on single-use plastics to carry out their activities safely is demonstrated, as well as the scarce protection and preparation of recyclers to carry out their work without exposing their health.

From Sánchez's perspective in his article "The post-pandemic challenges in solid waste management" he expresses:

While the rapid disposal of single-use products is often seen as beneficial to the health of staff and consumers, the imminent increase in the volume of this waste resulting from the COVID-19 pandemic challenges to overwhelm existing waste management systems that have not been able to cope with existing plastic waste satisfactorily. Pag (6)

Conclusions

The promotion of the circular economy must occur in all social spheres and in all business activities to change the linear paradigm that prevails in the country, in this process the private sector, the public and citizens in general must participate, being thus, the change of mentality is fundamental for the success of the transition process from the linear to the circular economy.

It must be recognized that ecodesign, the implementation of innovative technology and access to loans for circular

activities are fundamental for the development of the model, in addition the successful experiences of developed countries in the field of CD can be replicated since they offer the opportunity to improve through pedagogical, technological and social strategies.

The implementation of innovative technology is essential to achieve sustainability, therefore, the government must support the creation of companies that intend to operate with this economic model, resources must also be provided to those companies dedicated to the collection of solid waste to invest in equipment that allows them to be more efficient, in this way they ensure their economic sustainability, contribute to environmental and social sustainability, likewise citizens must be trained, aware of the importance of proper management of solid waste and companies must take responsibility for their waste, extended producer responsibility is fundamental to the success of THE EC.

Although one of the objectives at a global level is to reduce the use of single-use plastic, it is pertinent to recognize that with the presence of the pandemic its effectiveness in minimizing the proliferation of this is indisputable, the contribution of these plastics forces to recognize the importance of their permanence in sectors such as health and food, therefore, plastic is not the problem as erik Solheim puts it, the problem remains the same since before the pandemic.

Colombia, like other countries concerned about the consequences generated by the linear economic model, has become aware that it must generate strategies aimed at transition.

Resolution 1407 and the DANE reports allow the country to have clarity on the shortcomings and strengthens in the field of CD, however, the problem generated by the pandemic at a global level also tested the management of solid waste by becoming evident weaknesses in the collection systems, increasing the impact on ecosystems, affecting the fulfillment of the goals in terms of packaging.

However, it is pertinent to bear in mind that the responsibility for keeping Circular Economy strategies on the right track should not only fall on the State, the planet belongs to everyone and everyone is responsible.

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RESEARCH ARTICLE

Electricity Production Sources and CO_2 Emission in OECD countries: Static and Dynamic Panel Analysis

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Abstract

Industrialization, urbanization, population growth, and changes in lifestyle have all contributed to a rise in the OECD countries' risk of global warming. The amount of carbon dioxide (CO_2) generated from heat and power sources put out is directly related to how much electricity they make. Finding out which sources are bad for the environment, and which are not is the primary motivation behind this study. The impact of different approaches to energy production on carbon dioxide emissions is analyzed using OECD data. The data is analyzed using Quantile Regression (QR), Generalized Method of Moments (GMM), and Pooled Ordinary Least Squares (OLS). The study found that CO_2 emissions were significantly impacted in a positive direction when electricity was generated using coal, oil, or gas. The emissions from coal-fired power plants are the most detrimental. The generation of hydroelectricity and other forms of renewable energy can reduce CO_2 emissions in all regression models. The most compelling evidence of a correlation between CO_2 emissions and energy sources was uncovered in this study. In order to produce credible findings, the paper used both QR and GMM methods. Important implications for environmental policy are drawn from this article's findings. Both are required to lessen our reliance on fossil fuels and promote the development of renewable energy sources like solar, wind, and hydroelectricity.

Keywords: Carbon dioxide; Environmental impact; Economics; Renewable; Sustainability

Introduction

As the global economy grows, CO_2 emissions rise because of industrialization, deforestation, environmental damage, and the world's population (Raihan et al., 2018; Raihan et al., 2019; Jaafar et al., 2020; Raihan et al., 2021; Raihan and Tuspekova, 2022a). According to the World Meteorological Organization (2021), the amount of carbon dioxide in the air has increased by 2.5 times since the beginning of the industrial revolution. CO_2 can be emitted into the environment during the generation and consumption of energy (Raihan and Tuspekova, 2022b; Raihan et al., 2022a; Raihan et al., 2022b). The amount of greenhouse gases (GHGs) in the earth's atmosphere has significantly increased due to higher energy use and it has had numerous negative impacts on the environment, people's health, the economy, and many others (Begum et al., 2020; Raihan et al., 2022c; Raihan and Tuspekova, 2022c). More than 80% of the world's energy needs grew between 2000 and 2010. Most of this growth was made possible by using more than twice as many fossil fuels. Over 90% of all CO_2 emissions and over two-thirds of all GHG emissions come from burning fossil fuels and biomass (Raihan and Tuspekova, 2022d; Raihan et al., 2022d). This makes CO_2 the most critical factor in determining the overall GHG emissions trend (Raihan and Tuspekova, 2022e; Raihan et al., 2022e; Raihan et al., 2022f).

Most of the emissions in many countries come from the transportation and energy sectors (Raihan and Tuspekova, 2022f; Raihan and Tuspekova, 2022g). Since 2000, the OECD's economy has grown steadily, but CO_2 emissions related to energy have gone down. This has happened because of changes in the economy's structure and the energy supply and because manufacturing has become more

energy efficient. Most OECD countries are on track to meet their Kyoto Protocol emission reduction goal although the progress is not good enough. Because energy use and CO_2 emissions have recently increased, GHG levels will likely rise. Approximately 29% of GHG emissions in OECD countries come from the energy sector, 24% from transportation, 13% from manufacturing, 9% from agriculture, 7% from industrial processes, and 3% from waste (IEA, 2019). After three years of stability, CO_2 emissions from the world's energy sector hit a record high of 32.8 billion tons in 2017. In 2018, the average amount of CO_2 each person in OECD countries put into the air was 8.7 tons, while the average amount for the rest of the world was 4.3 tons.

Rapid economic expansion in OECD nations has coincided with an increase in energy usage for manufacturing, industrial, and service-oriented economic activities. Carbon, which is mainly used to make electricity and makes up most of the area's energy mix, has been the fastest-growing energy source in the OECD region over the last ten years. Even though this has helped the region grow and become more industrialized, it has also increased CO_2 emissions from energy use and air pollution, which is detrimental to human health (Raihan and Tuspekova, 2022h). Access to electric power sources has increased dramatically since 2000. Nonetheless, 45 million individuals living in the OECD region still don't have access to electricity, and many use biomass energy as their primary source of cooking fuel (IEA, 2019). However, energy consumption in OECD countries has been rising at a rate of 6% annually, indicating that the region's electric grid is having trouble covering its costs due to rapid population growth (IEA, 2019). In terms of global power consumption, it has been one of the regions with the quickest growth rates, with OECD nations leading the way. Indeed, the region has come a long way toward its objective of ensuring that everyone has access to power by 2030.

There may be numerous advantages to producing electricity for human usage. It could, however, hurt the environment and people's lives (Raihan and Tuspekova, 2022i; Raihan and Tuspekova, 2022j). Electricity can be produced in several ways, not all of which have the same environmental impact. Compared to other forms of renewable energy, such as solar power, the environmental impact of coal is substantially larger. In addition to nuclear and hydroelectric power facilities, oil can also be used to generate electricity. Coal, oil, and natural gas are frequently burned to generate electricity (Raihan and Tuspekova, 2022k). These factors contribute to the increase of carbon dioxide in the atmosphere. However, the location of power generation, transmission, and distribution can significantly alter the environmental consequences of the power system. Electric power systems also include transmission networks, distribution lines, and power plants that generate electricity from various fuel sources. Both the production and consumption of these items have the potential to have an impact on the natural world. Construction, electricity generation, component isolation, and separation fall within this category. The functional and construction effects can be further subdivided into operational effects (such as fuel sources and global and local pollutants) and building effects (manufacturing, installation, decommissioning, and disposal). However, energy-producing CO_2 emissions have not been the focus of any GMM or QR-based studies in the OECD region. Therefore, this research intends to identify a connection between CO_2 emissions and the sources of power generation in the OECD region using various methods, including System GMM, Difference GMM, and Quantile Regression. This article illustrates how much carbon dioxide is released from coal, gas, and oil electricity production in OECD countries. This study also demonstrated the advantageous effects of non-conventional methods of electricity production on the environment. This investigation aims to discover evidence that hydropower and other renewable energy sources can aid in decreasing waste and pollution. The environmental policy has been suggested in the article with the knowledge gained from this investigation.

Literature Review

The literature review overviews the relevant publications picked for the study endeavor. Numerous works have examined the relationship between power generators, renewables, and emissions of carbon dioxide. On the other hand, it's unclear how things happened because they happened in different ways, in different countries, and at different times. How much energy we use and how that affects CO_2 emissions is a big worry for people living now and in the future. Global citizens are already planning for the future consequences of climate change. Because of the harm, it does to the ecosystem; this is a dangerous situation. Dantama et al. (2012) reported that electricity influences all spheres of society, from the working class to the upper crust. According to numbers from 72 different countries, global CO_2 emissions increased from 67 million metric tons in 1990 to 134 million metric tons in 2012. So, environmental pollution kills more than 150,000 people yearly (Amri, 2017). Furthermore, Ozturk (2010) also linked various energy sources to economic growth. He examined several electricity sources. Population size, the quantity of renewable, fossil, and carbon-intensive energy used, nuclear-intensive energy used, over dense cities, and detrimental air pollutants like PM10, PM2.5, SO2, NO2, CO, and benzopyrene have all been related to the rise in global CO_2 emissions (Talbi, 2017). They also showed how these variables enhance global CO_2 emissions. Geothermal plants emit CO_2 due to their high temperatures (300–700 °F). The association between energy use, GDP expansion, and CO_2 emissions were examined using Granger causality and panel cointegration (Kristmannsdóttir and Armannsson, 2003). 70 countries' worth of data were analyzed from 1994-

2013. Granger causality studies show that the two are related to one another in terms of energy usage and carbon dioxide emissions. Cointegration tests demonstrated a long-term relationship between the variables of interest (economic growth and energy consumption) and CO_2 emissions. As a result of process fixes, rising energy use and economic growth led to lower CO_2 emissions. Economic activity, electricity concentration (demand strategy), heat production (supply strategy), and carbon emission index are all taken into account in this method of categorizing CO_2 emissions (demand policy effort). EU nations cut CO_2 more than non-EU nations. Reducing thermal power and increasing energy efficiency drove policy. These increases may be due to a shift in generation mix or higher power use. Scientists proved it (Kim et al., 2020).

Massive energy use and CO_2 emissions threaten future generations. Droughts, melting glaciers, rising seas, global warming, and heat waves are already happening. Negative environmental effects threaten the ecology. Between 1992 and 2018, Awosusi et al. (2022) analyzed the impact of BRICS biomass energy use. Environmental degradation is a byproduct of economic development, increased use of natural resources, and rising levels of gross capital. The research of Aydin (2019) relied on BRICS statistics from 1992-2013. Biomass energy's economic significance was emphasized. The heterogeneous panel data study benefited several nations. Biomass energy use is key to economic growth and reducing imports. Shisong et al. (2018) employed a quantile regression panel approach to estimate CO_2 emissions. According to their analysis, nonrenewable energy reduces CO_2 emissions the greatest. It is detrimental for high-emission nations to have little involvement in developing ecologically sound sources of power. Yu et al. (2019) investigated the effect of energy output on industrial development and long-term economic growth by concentrating on the nations with the most significant gains in power generation between 2000 and 2018.

From 1991 to 2018, the BRICS nations' electricity production contributed to industrial output and sustained economic growth. A few examples of these fields are manufacturing, raw materials extraction, mining, and chemical synthesis. It has significantly increased the electrification of all enterprises and households during the previous three decades (Wang et al., 2010). Apparently, the causal relationship between energy generation sources and CO_2 emissions has not been explored in OECD states. In addition, no other studies used system GMM, Difference GMM, and the QR approach to uncover useful information on CO_2 emissions from various power production sources in OECD countries. Consequently, the present study's results would help close a gap in the existing body of literature by using various econometric methods to identify a connection between CO_2 emissions and the sources of power generation in the OECD region.

Methodology

Data and variables of the study

Data for 38 OECD countries were obtained from the World Bank's World Development Indicators (WDI) database on an annual panel basis from 1986 to 2020. There are currently 36 member states of the OECD: Slovak Republic, Slovenia, Spain, Czech Republic, Denmark, Estonia, Finland, France, Netherlands, Norway, Poland, Portugal, Luxembourg, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Austria, Belgium, Japan, Korea, New Zealand, Israel, Switzerland, Canada, Chile, Colombia, Mexico, Costa Rica, the United States, Australia, Sweden, Germany, Turkey, the United Kingdom, and Lithuania. The following elements are taken into consideration (Table 1):

Table 1. A brief overview of the parameters

Name of the Variables	Variables in Log form	Elaboration of the Parameters
CO_2	L(CO_2)	CO_2 emissions (kt)
Coal	L(Coal)	Percentage of total electricity production that comes from coal
Gas	L(Gas)	Percentage of total electricity production that comes from gas
Nuclear	L(Nuc)	Percentage of total electricity production that comes from nuclear
Hydro	L(Hydro)	Percentage of total electricity production that comes from hydro
Oil	L(Oil)	Percentage of total electricity production that comes from oil
Renewable	L(Renew)	Percentage of total electricity production that comes from renewable resources excluding hydro

For a complete breakdown of how each variable was measured, the median, mode, standard deviation, and extreme values are displayed in Table 2. CO_2 has an average value that is greater than those of the other variables.

Table 2. Synopsis of Descriptive Statistics

Variables	Number of observations	Mean	Standard deviation	Minimum	Maximum
L(CO_2)	1172	11.17	1.707	5.458	15.57
L(Coal)	891	2.760	1.787	-6.483	4.587
L(Gas)	988	2.162	1.756	-4.785	4.599
L(Oil)	1071	0.864	2.017	-6.091	4.605
L(Renew)	961	0.467	1.924	-8.028	4.181
L(Hydro)	968	1.860	2.253	-6.528	4.601
L(Nuc)	867	3.347	0.789	-2.433	4.477

Econometric model specification

Coal, gas, oil, renewable energy, nuclear, and hydroelectricity are the main ways electricity can be produced. Though there are many ways to produce electricity, but there is no available data for these sources. Using the standard methodological approach, this investigation controls CO_2 emissions by measuring the impact of power generation from coal, natural gas, nuclear, hydroelectric, oil, and renewable sources. The following equation (1) may be used to determine the influence of dependent and independent variables.

CO_2 = *f* (Coal, Gas, Oil, Renewable, Hydroelectric, Nuclear) (1)

Notably, no dummy variables were included; all variables were classified. This is because it is anticipated that data behavior would not change over time. The multivariate econometric model is depicted in Equation (2).

$$(CO2)_{it} = \beta_0 + \beta_1(Coal)_{it} + \beta_2(Gas)_{it} + \beta_3(Oil)_{it} + \beta_4(Renew)_{it} + \beta_5(Hydro)_{it} + \beta_6(Nuc)_{it} + \varepsilon_{it} \quad (2)$$

The log transformation has been taken in Equation (3).

$$L(CO2)_{it} = \beta_0 + \beta_1 L(Coal)_{it} + \beta_2 L(Gas)_{it} + \beta_3 L(Oil)_{it} + \beta_4 L(Renew)_{it} + \beta_5 L(Hydro)_{it} + \beta_6 L(Nuc)_{it} + \varepsilon_{it} \quad (3)$$

where β_0 is the intercept term. β_1, β_2, β_3, β_4, β_5, and β_6 are the slope coefficients. The ε is present the residual, and i presents the cross-section country, t presents the time.

GMM approach

Researchers often utilize both fixed and random effects models when studying topics such as international trade, environmental policy, and economic development. The dynamic GMM model, developed by Arellano and Bond (1991) has only recently begun its operations in these sectors. This study used models with fixed and random effects separately so that their findings can be compared with those obtained from our dynamic model. In order to conduct an investigation into the CO_2 emissions, a two-stage "differenced" and "system" GMM model has been included in this investigation. Formulae for the differenced GMM and system GMM can be displayed as Equation (4) and Equation (5).

$$L(CO2)_{it} = \beta_0 + \beta_1 L(CO2)_{it} + \beta_2 L(Coal)_{it} + \beta_3 L(Gas)_{it} + \beta_4 L(Oil)_{it} + \beta_5 L(Renew)_{it} + \beta_6 L(Hydro)_{it} + \beta_7 L(Nuc)_{it} + \varepsilon_{it} \quad (4)$$

$$L(CO2)_{it} - (CO2)_{it-1} = \beta_0 + [\beta_1 L(CO2)_{it} - (CO2)_{it-1}] + [\beta_2 L(Coal)_{it} - (Coal)_{it-1}] + [\beta_3 L(Gas)_{it} - (Gas)_{it-1}] + [\beta_4 L(Oil)_{it} - (Oil)_{it-1}] + [\beta_5 L(Renew)_{it} - (Renew)_{it-1}] + [\beta_6 L(Hydro)_{it} - (Hydro)_{it-1}] + [\beta_6 L(Nuc)_{it} - (Nuc)_{it-1}] + (\eta_{it} - \eta_{it-1}) + (\varepsilon_{it} - \varepsilon_{it-1}) \quad (5)$$

Quantile regression (QR regression)

One important use of the quantile regression method is to study outcomes that aren't normally distributed and don't have linear relationships with predictor factors. Buchinsky (1994) states that to describe the possible different effects, it needs to identify the qth-quantile (0< q<1) of the dependent variable as a temporary distribution, given a set of x_i variables as follows:

$$Q_q(y_{it} \mid \beta_0, \varepsilon_{it}, x_{it}) = \beta_0 + \varepsilon_{it}^q + \beta_i^q x_{it} \quad (6)$$

where y_t indicates the rate of CO_2 emission over time.
As seen by the following objective function, inference from the qth quantile regression requires minimizing the absolute value of the residual. Quantile regression is presented in Equation (7).

$$Q_q(\beta_i^q) = \min \beta \sum_{q,i,t=}^{n} \| y_{it} - x_{it}\beta_i^q \| = \min \left[\sum_{i:y_{it} \geq x_{it}\beta} q \left| y_{it} - x_{it}\beta_i^q \right| + \sum_{i:y_{it} < x_{it}\beta} (1-q) \left| y_{it} - x_{it}\beta_i^q \right| \right] \quad (7)$$

Results and Discussion

Correlation analysis is crucial to know if there is a positive or negative correlation between the variables in the study. When two variables have a positive correlation, it can say that they are positively covariant. Negative covariance is formed when two variables have an inverse relationship. Table 3 correlations show a positive relationship between L(CO_2) and L(Coal), L(Oil), and L(Gas). The correlation between L(CO_2) and L(Coal) is the highest and most significant, while the correlation between L(CO_2) and L(Gas) is the lowest and least significant (0.014). Similarly, the strongest positive correlation is found between L(CO_2) and L(Coal) and the value is 0.360. There are no correlation coefficients that are greater than 0.80 between any of the variables in this research. As a result, there is no multicollinearity and the study's variables are not linked to one another. To a lesser extent than L(Nuc), L(Renew), and L(Hydro) have a negative correlation with L(CO_2).

Table 3. Indicators of variable correlation

Variables	L(CO_2)	L(Coal)	L(Gas)	L(Oil)	L(Renew)	L(Hydro)	L(Nuc)
L(CO_2)	1.000						
L(Coal)	0.360***	1.000					
L(Gas)	0.014	0.212***	1.000				
L(Oil)	0.197***	0.480***	0.089***	1.000			
L(Renew)	-0.098***	-0.017	0.303***	-0.260***	1.000		
L(Hydro)	-0.180***	-0.383***	-0.169***	-0.256***	0.140***	1.000	
L(Nuc)	-0.353***	-0.286***	-0.423***	-0.172***	-0.262***	0.264***	1.000

*** p<0.01, ** p<0.05, * p<0.1

Table 4. Unit Root Test Result

Variables	At Level			At 1st Difference		
	Harris-Tzavalis	Im-Pesaran-Shin	Levin, Lin & Chut	Harris-Tzavalis	Im-Pesaran-Shin	Levin, Lin & Chut
L(CO_2)	0.488	0.847	-0.471	-23.45***	-8.765***	-5.613***
L(Coal)	1.254	2.294	4.70	-32.44***	-9.213***	-7.29***
L(Gas)	-0.94	1.167	0.362	-32.10***	-8.956***	-5.15***
L(Oil)	1.2456	-0.863	-0.073	-21.25***	-9.33***	-7.88***
L(Renew)	-0.98	-0.736	-0.684	-31.83***	-9.247***	-7.82***
L(Hydro)	-1.11	0.617	0.545	-39.52***	-9.769***	-7.72***
L(Nuc)	-2.18	-1.054	-1.028	-44.82***	-10.75***	-9.687***

*** p<0.01, ** p<0.05, * p<0.1

Empirical economists frequently use panel unit root tests, although there is still room for debate on how to interpret the results. This note elaborates on how the rejection of the panel unit root hypothesis can be read as proof that a sizable fraction of the units are stationary. For this reason, it is suggested that, in the case of a rejection, especially in contexts where the temporal dimension of the panel is quite large, the test outcome be supplemented with an estimate of the fraction of the cross-section units for which the individual unit root tests are rejected. The rejection's monetary impact can be gauged by how much this percentage rises (Pesaran, 2012). The outcomes of a unit root test for the dependent and independent variables are shown in Table 4 for both the raw data and the first difference levels. Specifically, it shows that H(0) has a unit root since it is non-stationary, while H(1) does not. It is evident that all of the parameters are locked in at H(1). The null hypothesis is rejected with a confidence level of 5% if there is even a nominal difference between the two variables. The dependent and independent variables are anticipated to follow a unit root distribution. Here, the investigation would reject the null hypothesis if the p-value is less than 0.01.

As shown in Table 5, the log-log model estimates both fixed and moving information panels. The coefficient of CO_2 emissions and electricity output from various sources are presented in columns 2 and 3 of the model. The coefficient represents a percentage change in CO_2 emissions due to a percentage change in the independent variables. Our model's dynamic panel regression is shown in columns 4 and 5. The estimate is statistically significant and positive, with coefficients of L(CO_2) for explaining L(Coal) of 0.108*** and 0.109*** in the fixed and random effect models, respectively. The differenced GMM model predicts a 0.0629 percentage point rise in CO_2 emissions for a one percent increase in L(Coal), while the System GMM model predicts a 0.00802 percentage point decrease. Direct sources of CO_2 emissions are important, but indirect sources

including hard coal, natural gas, and non-energy consumption also contribute significantly (Huang et al., 2018). For cases where both L(Coal) and L(Oil) are major contributors to increasing CO_2 in a given panel research region, the second-phase output is determined by the dynamic GMM model. L(Renew) exhibits a -0.0101 and -0.0101 coefficient weighted negative and significant effect on L(CO_2) in both the fixed and random effect models. For the differenced GMM model, a 1% increase in L(Renew) leads to a 0.00605% rise in CO_2 emissions, while for the System GMM model, the growth is only 0.00485%.

In the same way, the Differenced GMM model predicts a 0.0417% drop in CO_2 emissions for a 1% rise in L(Hydro), while the System GMM model predicts a 0.0042% drop. Table 5's Haussmann chi-square value of 18.52** favors the fixed-effect model over the random-effects model, with a significance level of 0.125. The system GMM model only differs considerably in sign and direction from the fixed-effect model for L(Oil). To ensure the internal consistency of the system GMM estimate, it is assumed that the error term is not serially correlated. Due to the low AR-2 values for both models, we cannot conclude that the first-differenced error at order 2 is serially correlated. Methods that can be relied on are required for use in GMM estimations. Applying the Sargan and Hansen tests for over-identifying constraints in estimation allows one to examine the general validity of an instrumental variable. The null hypothesis assumed that all instruments were reliable because they were considered exogenous. This study shows that the Hansen test returns probabilities between 0.243 and 0.415. On the other hand, the Sargan test statistics of the present investigation yield probability values of 0.250 and 0.284. The null hypothesis that the instruments are reliable, was accepted for both.

Table 5. Dynamic and Static Panel Regression Result

Variables	Fixed effect	Random effect	Differenced GMM	System GMM
L(CO_2)			0.716***	0.980***
			(0.0629)	(0.00802)
L(Coal)	0.108***	0.109***	0.0779**	0.0130*
	(0.0142)	(0.0141)	(0.0335)	(0.00881)
L(Gas)	0.0797***	0.0801***	0.0411***	0.00583**
	(0.0113)	(0.0112)	(0.0134)	(0.00459)
L(Oil)	0.0374***	0.0377***	0.00896	0.00861
	(0.0103)	(0.0103)	(0.00561)	(0.00614)
L(Renew)	-0.0101	-0.0101	-0.00605	-0.00485
	(0.00665)	(0.00662)	(0.00520)	(0.00318)
L(Hydro)	-0.0629***	-0.0623***	-0.0417*	0.00421*
	(0.0139)	(0.0138)	(0.0296)	(0.00495)
L(Nuc)	-0.0358**	-0.0361**	-0.00215	-0.00666
	(0.0161)	(0.0160)	(0.00542)	(0.00853)
Constant	12.15***	12.07***	3.287***	0.207**
	(0.0847)	(0.377)	(0.727)	(0.101)
Hausman test		18.52**		0.004
AR-1				0.184
AR-2				
Hansen Test			0.243	0.415
Sargan Test			0.250	0.284
Number of instruments			306	334
Observations	805	805	675	692
R-squared	0.334			
Number of countries	28	28	25	26

*** p<0.01, ** p<0.05, * p<0.1

Furthermore, Column 2 of Table 6 displays the results of an OLS regression between CO_2 emissions and power generation from different sources. Colum 3 through Colum 5 display the regression quantiles. The QR model considers all three of these frequencies: Q25, Q50, and Q75. Coal and natural gas power plants produce more carbon dioxide as they generate more electricity. In the QR models for Q25, Q50, and Q75, the L(Coal) coefficients to explain L(CO_2) are 0.0607, 0.209***, and 0.481***, respectively. There is a negative and significant effect on L(CO_2) from both L(Renew) and L(Hydro), except for Q25. With quantile-specific L(Renew) values of 0.0235, -1.102*, and -0.0327, respectively, a 1% increase in L(Renew) sources generates a CO_2 emission barrier of 0.024%, 0.10%, and 0.034%. There is a statistically significant inverse relationship between carbon emissions and the generation of power from renewable and hydroelectric sources; this is an important factor to consider. Power generation from renewable, oil, and hydroelectric sources can thus contribute to improved environmental quality by lowering atmospheric carbon emissions. In addition, less carbon dioxide is released into the air when power generation is more streamlined.

Table 6. Quantile regression outcomes

Variables	Panel OLS	Q25	Q50	Q75
L(Coal)	0.258***	0.0607	0.209***	0.481***
	(0.0486)	(0.0830)	(0.0637)	(0.0336)
L(Gas)	0.316***	0.131	0.492***	0.268***
	(0.0707)	(0.121)	(0.0926)	(0.0489)
L(Oil)	0.346***	0.541***	0.211***	0.0846**
	(0.0611)	(0.104)	(0.0801)	(0.0422)
L(Renew)	-0.0171	0.0235	-0.102*	-0.0327
	(0.0455)	(0.0776)	(0.0595)	(0.0314)
L(Hydro)	-0.248***	-0.249	-0.127***	-0.08***
	(0.0427)	(0.0729)	(0.0560)	(0.0295)
L(Nuc)	-0.136	-0.216	-0.0683	0.0791
	(0.0841)	(0.143)	(0.110)	(0.0581)
Constant	10.79***	11.24***	10.39***	10.34***
	(0.373)	(0.636)	(0.488)	(0.258)
Observations	405	405	405	405
Number of ids	32			
R-squared	0.742			

*** p<0.01, ** p<0.05, * p<0.1

In most cases, coal, oil, and gas are the primary fuels utilized in the generation of electrical power. Degradation of the local environment is exacerbated by these countries' use of fossil fuels for energy production, particularly coal, oil, and natural gas. The present study focused on answering the question of what can be done to reduce the carbon dioxide emissions of power plants. It is untrue to assume that the only way carbon dioxide is released into the atmosphere is through the burning of fossil fuels like coal, oil, and gas. Our novel approach to this issue is based on a hybrid of the conventional least squares method, a variant of the method of moments, and the quantile regression technique. No other scientific study has ever attempted something like this before. Because this study care about the accuracy of both the methods and results, this investigation consistently mixes the two. Massive increases in CO_2 emissions are produced when fossil fuels like gas, coal, and oil are burned. It is possible that switching to renewable energy sources like hydropower might drastically reduce pollution levels (Voumik et al., 2022a; Voumik et al., 2022b; Voumik et al., 2022c) The GMM method proves that burning coal and extracting oil are the two leading causes of CO_2 emissions. CO_2 emissions may be reduced, however, if power is generated from renewable and hydroelectric sources, as shown by the GMM approach. Quantile regression analysis of emissions data provides some context, showing that coal and natural gas are the two most important contributors to air pollution and, by extension, global warming. Hydropower and other renewable energy sources have the potential to aid in emission reductions, as shown by the GMM and Quantile Regression methods. Hydroelectricity and other forms of renewable energy are favored by all economic models as the most effective means of minimizing harmful effects on the environment (Huang et al., 2018; Aydin, 2019). Coal-fired energy is much more damaging to the environment than other forms of pollution. This study's aims are met as a result as well. It is generally accepted that the environmental impact of electricity generated by burning coal is more significant than that of power generated by burning oil or natural gas. However, hydroelectricity production is better for the environment than renewable energy sources that don't use hydropower. This paper's contribution quantifies how the independent factors affected the dependent ones. Potentially significant long-term renewable energy sources include wind, solar, geothermal heat, and biomass. The majority of OECD countries get their power from coal and oil. Coal and gas consumption in the OECD as a whole has expanded quickly since 1980; however, consumption has declined in some countries like New Zealand and Norway, and demand in the United States currently surpasses output, which is rising at a high rate.

Conclusions and Policy Implications

This study examined the relationship between energy consumption and carbon dioxide emissions in OECD economies. Using panel generalized methods of moments (GMM) and quantile regression, this research analyzed time series data on OECD nations from 1986 to 2020. The research empirically assessed the impact of different power generation sources on CO_2 emissions using quantile regression and generalized linear models (GMM). When compared to traditional statistical methods like ordinary least squares (OLS), generalized linear models (GLM), and additive random effects (ARDL), quantile regression, one step-difference GMM, and system GMM provide a more comprehensive explanation of the overall dependence of energy generation from diverse sources on CO_2 emissions. As a result of their more significant outputs, coal and natural gas have more prominent production factors. Production rates of renewable energy are inversely proportional to their ecological footprint. Because of the positive ecological effects, renewable energy sources should be prioritized above traditional ones. CO_2 emissions and energy

generating sources are positively correlated in OECD countries. Hydroelectric power generation also can lessen its impact on the environment. Thus, renewable energy sources are preferable to conventional electricity generation methods. Natural gas and coal are two of the most widely used energy sources, and all of our models for OECD nations indicated a high positive correlation between the two in terms of CO_2 emissions. Regardless, the oil-based power generation didn't give us any direct orders.

This article provides a clear and consistent picture of the current state of renewable energy sources in OECD countries. Since most OECD nations have abundant natural resources, this article shows they have a great chance to meet their overall power demand by using their renewable resources, such as solar, wind, geothermal, hydropower, ocean energy, and bioenergy. If they can maximize their usage of renewable energy sources, not only will their electricity needs be met at a low cost, but their CO_2 output may also be kept to a minimum. So, instead of relying solely on conventional ways, now is the time to look forward and collaborate with these renewable energy areas to produce electricity. There has already been some effort made by OECD governments to resolve the power situation. Alternative energy sources, such as solar power, should be given more attention because they represent a promising new industry with the potential to supply the vast majority of the OECD's population's energy and power needs. Combined with other forms of renewable energy, these can significantly help meet their daily power needs. OECD countries may be able to meet their future electricity needs using these resources to generate electricity. To alleviate the power shortage situation in their respective regions, governments and the private sectors should collaborate to emphasize using renewable energy sources for electricity generation. The article also provides a brief overview of the current state of renewable energy worldwide. With fossil fuel reserves continuously dwindling, the world must increasingly rely on renewable energy sources to keep up with increasing energy demands. By maximizing the utilization of renewable energy sources, this article is the first step toward building a completely uninterrupted power flow that is both environmentally friendly and efficient.

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RESEARCH ARTICLE

Prospect for green policing: Constructs and dimensions of environmental sustainability in the context of public safety

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Abstract
The vulnerability of the environment to the risk posed by climate change becomes even more exponential with the rapid phase of the industrial revolution and globalization in the contemporary era. As a key pillar of sustainability, the role of every societal sector is critical in the consummation of environmental equilibrium. This study was carried out to develop a common framework for the programming of green activities in the realm of public safety sectors and to establish standardized indicators for the coordination and complementation of environmental sustainability efforts and initiatives. The study employed a quantitative research design that supports the use of an instrument to explore the constructs and dimensions of environmental sustainability in public safety through Principal Component Analysis (PCA) via Exploratory Factor Analysis (EFA). The data harbored a 0.964 index on the Kaiser-Mayer-Oldin (KMO) Measure of Sampling Adequacy which implies that the explored constructs are highly correlated. Similarly, Barlett's Test of Sphericity demonstrated strong significance with a value of .000, implying that all indicators are factorable. Furthermore, the Scree plot revealed that there are two (2) dimensions that yielded an Eigenvalue that is equal to or greater than 1 ($\lambda=\geq1$) namely Green Behavior and Sustainable Operations. The explored constructs and dimensions are necessary for the development of a model for Green Policing which can serve as a basis for monitoring and evaluation of environmental law enforcement and environmental sustainability efforts of the public safety sectors.

Keywords: green behavior, sustainable operations, public safety sectors, indicators

Introduction

In recent years, a wide range of megatrends in the spectra of demographic upheavals, economic and social dynamics fluctuation, technological advancement, and environmental degradation have accelerated global concerns of sustainable development (Lefevre et al., 2022). In the environmental landscape, a key tenet of Sustainable Development, organisms' habitats are diminishing, the capacity to repair biodiversity is dwindling, the climate is changing, invasive alien species are exponentially rising, and natural resources are under unprecedented demand.

The World Economic Forum (WEF) Report argued that the most significant concerns for the next five years are social and environmental risks. Over a 10-year horizon, environmental concerns takes the center stage of the global environment's health. Environmental issues and challenges are regarded as the five most serious long-term dangers to the globe, and possibly damaging to people and planet. Accordingly, rated as the top three most serious risks relative to environment are climate action failure, extreme weather, and biodiversity loss (WEF, 2022).

For instance, pollution impacts every part of the earth, affecting our health through the food we eat, the water we drink, and the air we breathe. Pollutants such heavy metals and organic chemicals, as well as those used in electrical insulators and flame retardants, have been detected in plant and animal tissues even at the most distant areas like polar ice caps, deep abyssal seas, and high mountains (Jamieson et al., 2017). According to the World Health Organization, environmental causes account for approximately one-quarter of all deaths worldwide, or 12.6 million people in 2012, with at least 8.2 million attributable to non-communicable environmental causes and more than three-fourths occurring in just three locations (Prüss-Üstün et al., 2016).

The Global Dangers Report of the World Economic Forum's in 2018 outlined that six of the ten largest risks that might afflict the world in terms of likelihood and effect are environmental in nature (WEF, 2018). Existentially, all

sorts of ecosystems and biomes, as well as all the processes and mechanisms that manage the Earth system's balance and resilience, are under great stress (Aukema et al., 2017; Collins, 2018). This phenomenon of worldwide environmental deterioration offers a serious threat to social and economic growth and development, and its consequences necessitate the intervention of public safety or law enforcement.

In response to the 1992 Earth Summit in Rio de Janeiro, a slew of international accords and national environmental laws are in existence, and they are carried out by environmental regulation and enforcement among public safety and law enforcement organizations. However, since environmental deterioration continues at its sophisticated high, present environmental legislation implementation is not as successful as intended in halting environmental damages (Vogel et al., 2016). These limitations are the result of a variety of causes, including limited human capacities, leadership and management, a lack of access to technology, unpredictable economic development, and expansion, and the transboundary character of environmental impacts, among others (Baloch et al., 2020; Soga & Gaston, 2018; UNEP, 2018).

Because the implementation of environmental law necessitates adaptation, countries' implementation and compliance practices and strategies shift from relying solely on severe penalties for environmental violations to viewing compliance through criminal sanctions to heed action for substantial compliance (Paddock et al., 2017). Agenda 21, a global roadmap or blueprint for sustainable development born out of the 1992 United Nations Conference on Environment and Development (UNCED) Earth Summit and heeded by the Philippines through Philippine Agenda 21, recognizes the importance of public safety law enforcement in enabling legislation to effectively manage the environment and promote sustainable development in full swing.

The role of public safety sectors particularly the law enforcers or police is critical in the attainment of environmental sustainability. Given this importance, most law enforcement agencies fail to examine the environmental impact of their operations (Konyk, 2018). Alarmingly, according to the United Nations Environment Programme (2014), environmental deterioration is rising, and the current environmental law enforcement in almost all developing countries of the world is not as effective as may be desired. This can be attributed to constraints in human capacity and access to technology; nationwide push toward poverty alleviation and rapid economic growth; and, most importantly, a lack of knowledge of potential solutions that could be appropriate, or resilient to countries' environmental policing needs (UNEP, 2014). More so, there is a dearth of study and literature vis-à-vis Green Policing and environmental sustainability in the parlance of public safety and in the context of public safety sector. Evidently, studies on environmental sustainability primarily pitched into the efforts undertaken by educational institutions, businesses and enterprise, and other government institutions, and study on sustainability initiatives, most specifically Green Policing, is almost nil, if not nothing at all.

This study was borne out of the aforementioned realities. As environmental problems worsen, the role of public safety, particularly law enforcement, becomes increasingly important. This study explored the constructs and dimensions of environmental sustainability in public safety, prospecting the concept of Green Policing as a strategy to complement sustainability and public safety in promoting a green community.

Literature Review

Legal Foundation

Sustainable development was previously established as a policy in the Philippines as early as the 1970s, long before the concept gained international recognition. This is based on Presidential Decree No. 1151 of 1977, also known as the Philippine Environmental Policy (PEP), which urged the broadest range abuse of resources (exploitation), subject to the circumstance that it will not destroy or pose threat to humanity’s health and safety, and that it will not set conditions that are detrimental to country's economy by and large (de Guzman, 2012). The Philippine Strategy for Sustainable Development (PSSD) that was crafted in 1987 is the country's most robust approach for attaining the twin pillars of sustainable development back in the 1980s: economic growth and environmental integrity. During the time, social development did not emerge as a pillar of sustainable development until ten years later, when the Philippine Agenda 21 (PA21) was established. Following the PEP declaration came the Philippine National Strategy for Sustainable Development framed in 1989 and the Action Plan for Sustainable Development, commonly called as Philippine Agenda 21. The 1989 strategy aimed for economic growth while protecting the country's biological variety, key ecosystem services, and overall environmental quality. The Philippine Agenda 21 also established parameters for long-term national development and centered economic development on ecological responsibility and improved on the PEP by shifting the emphasis from maximum output to "suitable productivity" within the bounds of the physical environment's carrying capacity, in some ways (Lasco et al., 2018).

Clearly, as a response to the 1992 United Nations Conference on Environment and Development, also known as the Earth Summit, the PA21 became the country's national agenda for sustainable development in the 21st century. Consequently, in addition to providing enabling policies for economic and environmental sustainability and integrating the concept of sustainable development into the

framework of governance of the country, the action agenda enshrined in PA21 explicitly highlighted investments in "human and social capital, health, population management, and human settlements, while also acknowledging the need to address" community poverty and other pressing social issues (Haque, 2017; Howes et al., 2017). Today, PA 21 is still used as the pertinent document for the government's sustainable development policy.

The Philippines has been a pioneer in enacting laws and regulations concerning the environment and natural resources (ENR). The government has passed several laws and established agencies over the years to manage, protect, and conserve the country's environment and natural resources (World Bank, 2009). The 1987 Philippine Constitution, which clearly and explicitly regarded the right of people "to a balanced and healthful ecology in accordance with the rhythm and harmony of nature," established the country's commitment to all aspects of sustainability including towards environmental preservation and protection, economic growth and development, and social justice and equity promotion (Delloro & Gonzalez III, 2021).

The creation of the MidTerm Philippine Development Plan (MTPDP) 2004–2010 and the country's commitment to the Millennium Development Goals bolstered the sustainable development agenda even more. It recognized five (5) environmental and natural resource sector targets, namely, maintaining self-sustaining and more productive usage of available resources to encourage investments and entrepreneurial spirit; promotion of sustainable mining operations that conform to the principles of sustainability: economic growth, environmental protection, and social equity; reinforcing protection provided to vulnerable and ecologically-fragile areas; ensuring a healthy environment for the people; and preventing the incidence of natural catastrophes in order to save lives and properties (World Bank, 2009).

Following that, in September 2015, the 192 United Nations (UN) member states including the Philippines, made an agreement to pursue efforts in attaining the seventeen (17) Sustainable Development Goals (SDGs) and the associated 169 objectives by 2030. The 17 Global Goals encompass the sustainability pillars (environmental, social, and economic). The underlying objectives or targets for each goal relate to the Sustainable Development theme *no one is left behind*. It was then recognized that the Global Goals are crucial in the fulfillment of the long-term vision delineated in AmBisyon Natin 2040 (Reyes et al., 2019).

The concept of Green Policing is based on the existence of campaigns and the implementation of environmental laws and programs by the Philippine National Police in accordance with its core value *Makakalikasan* (pro-environment), which is centered on environmental protection and conservation in order to maintain ecological balance.

As per Executive Order Nos. 23 and 26, series of 2011, the Department of Environment and Natural Resources (DENR) as the primary government agency in charge of conserving, managing, developing, and using the country's environment and natural resources launched the National Greening Program (NGP) as the agency's banner program in 2011, with the goal of implementing sustainable management of natural resources through resource conservation, protection, and productivity enhancement, as well as consolidating and harmonizing all greening efforts of the government, civil society, and the private sector, among others. Through the PNP LOI 42-09 (Project T.R.E.E.s.) "Pulis Makakalikasan: 10 Milyong Puno, Pamana sa Kinabukasan" project, the DENR has collaborated with the Philippine National Police. Other than tree-growing operations as the main focus of Pulis Makakalikasan, there have also been environmental initiatives such as clean-up drives on the town's streets and coastal regions, as well as beneath the water via Pulis Scubasureros. The cleanliness of police camps and stations is one aspect of the Intensified Cleanliness Program (ICP). These fundamental values and green policing initiatives are expected to be implemented in all police stations around the country.

Sustainability and Its Overarching Pillars

Environmental risks are associated with greater rates of violence. This is related to system processes, in which resource scarcity and violent conflict fuel one another, establishing a chain reaction (IEP, 2021). Rockström et al., (2009) argues that if one environmental problem is not fixed, the other will be adversely affected such that one environmental problem does not remain fixed in its current condition but rather worsens other environmental concerns in a domino effect. For instance, the habitat loss has an impact on agricultural productivity as well. An "indirect" ecological function is the loss of pollinators which results in lower harvests of native pollinators species of plants (Nilsson, 2019).

When one views sustainability as a three-pronged pillar comprised of the environment, the economy, and society, or as a dualistic connection between humans and the ecosystems they occupy, there should be consensus that maintaining the supply of clean air, clean water, and clean and fertile land is fundamental to a sustainable socioeconomic system. It is evident that creating a sustainable civilization would be hard or impossible without a sustainably suitable environment to offer a resource basis. Likewise, a sustainable economy is dependent on a continuous material flow, energy, and natural resources for without it, the economic systems will fail (Morelli, 2011).

As supported by (Gibson, 2010), sustainable development is an ever-changing process. The sustainability of social, economic, and environmental systems is inextricably

intertwined thus, while building a sustainable development paradigm, possible trade-offs among these three pillars of sustainability must be addressed. Extreme event risk and trade-offs between economic growth, social wellbeing, and the environment are examples of environmental sustainability links.

Environmental Sustainability Framework for Public Safety

On the level of policies for sustainability, Howes et al., (2017) claimed that there is a plethora of new policies, spanning from international treaties to national initiatives, environmental regulations at several levels of the government, regional programs, and even local plans and programs. Nonetheless, years of scientific monitoring reveal that the globe is no closer towards achieving environmental sustainability. In fact, the situation is worsening, with policy implementation failure playing a large role. Howes and colleagues further stress that multiple literature demonstrates that the inability of environmental policies to achieve their intended goals is related to economic, political, and communicative problems. Overlaps between environmental and economic development objectives, insufficient resources to adopt environmental regulations, and inability to meet objectives to various stakeholders are all crucial factors contributing to the nonattainment of environmental sustainability.

According to the United Nations Environment Programme, environmental deterioration is rising, and the current environmental law enforcement in almost all developing countries of the world is not as effective as may be desired (Holley, 2017; UNEP, 2014). As environmental problems worsen, the role of public safety, particularly law enforcement, becomes increasingly important thus, environmental law enforcement must evolve. As a result, states have begun to shift their strict enforcement processes and operations away from relying solely on the imposition of strict sanctions for environmental violations or towards viewing punitive measures as just one of the components of a set of actions that national governments must aim to accomplish substantial compliance. As the link between national and international laws on environment becomes more significant and recognized, it is evident that effective and efficient enforcement and implementation of environmental laws is required if international environmental legislation is viewed to be sustainable.

UNEP (2014) also reported that in emerging and transition economies, some of the policy instruments have frequently not transpired in concert with investment in employee capacity, knowledge bases, or equipment due to conflicting priorities. Failure to pay enough attention to inspection and monitoring, as well as failure to put processes in place for engaging the regulated community and discouraging infractions, fosters a culture of impunity and undermines the efficacy of environmental legislation and enforcement. The report also suggests that as technology progresses and the world is at its rapid pace, an effective enforcement necessitates executives staying to stay on top of appropriate and updated technological tools and equipment to empower law enforcement officials to fulfill their duties more effectively and efficiently, thus, appropriate training must be prioritized to enhance and upskill the capacity of police agencies.

Methodology

Research Design

This study employed a quantitative technique that promotes the use of a research instrument to determine the indicators of environmental sustainability in public safety and to identify the possible dimensions of Green Policing as a basis to develop a green strategy for the public safety sectors. The identification of the indicators of environmental sustainability in public safety was validated by key experts from the Department of Environment and Natural Resources (DENR) and Philippine National Police Region 12.

Research Respondents/Locale

Upon consolidation, the indicators identified were then tested on the respondents who were the police officers in the eight (8) police stations under the General Santos City Police Office (GSCPO) that are strategically established to deliver basic police services in all twenty-six (26) barangays of the city.

Sampling Technique

The population was established using stratified random sampling, a probability sampling approach in which the researcher divides the overall population into subgroups to represent a population (Acharya et al., 2013). This makes it easier for the researcher to glean relevant inferences from the responses. Using this sampling strategy, the researcher randomly picked respondents who fit the target group using a confidence interval of 5%.

Data Administration and Collection

The administration and collection of data were made through digital forms.

Data Analysis

The responses obtained were statistically treated and analyzed utilizing Exploratory Factor Analysis (EFA) through Principal Component Analysis (PCA) to sequentially standardize linked metrics and examine the

underpinning factor structure of a set of observed variables without attempting to impose a predetermined structure on the conclusion (Knekta et al., 2019; Suhr, 2006). EFA, as the name suggests, explores the latent and manifest constructs or variables.

Results And Discussion

Kaiser-Mayer-Olkin and Barlett's Test of Sphericity

The KMO (Kaiser-Mayer-Olkin) index is a statistical test that determines if the correlation between variables is too low for a factor model to be regarded as adequate (Watkins, 2018). It is a more accurate measure of factorability since it determines if the correlation coefficients within the data are close enough to zero to indicate that there is at least one (1) latent factor underlying the variables, with 0.50 being the minimum acceptable value ((Smyth, R. & Jonhson, 2016).

Table 1 shows the result of the Kaiser-Mayer-Oldin measure of Sampling Adequacy and Barlett's Test of Sphericity result for the dimensions of environmental sustainability in the context of public safety. The KMO value of .964 implies that the sample is in high correlations and that the 286 sample size is sufficient for analyzing the dimensions of environmental sustainability.

Correspondingly, Barlett's Test of Sphericity showed high significance with its value of .000, which is less than .001, and therefore further implies that all items are factorable (Williams et al., 2010).

Table 1. KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		.964
Bartlett's Test of Sphericity	Approx. Chi-Square	7217.072
	df	210
	Sig.	.000

Scree Plot Analysis

The Scree plot is a graphical representation of the total variance of data suited by the total initial Eigen value vs the number of components or indicators (Frey, 2018). Through the Scree Plot Analysis, first step in factor analysis is deciding how many factors to extract in order to produce the most parsimonious (but still interpretable) factor structure. Drawing a straight line across the plotted eigenvalues, beginning with the greatest, the last point on this line symbolizes the last factor extracted, with the notion being that any more variation explained beyond this point is meaningless (Smyth & Jonhson, 2016).

The Scree plot below reveals that there are two (2) factors or dimensions that yield an Eigenvalue that is equal to or greater than 1 ($\lambda = \geq 1$). Starting with the initial element, the slope gradually descends until it approaches a semi-vertical horizontal line formation, as shown in Figure 1.

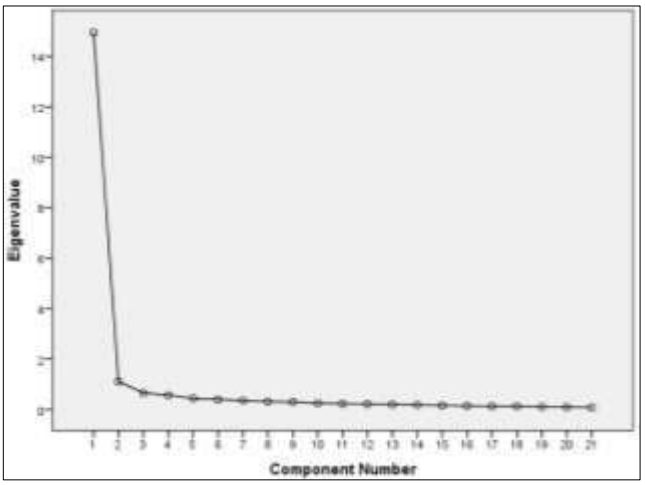

Figure 1. The Scree Plot

Constructs and Dimensions of Environmental Sustainability in Public Safety

The result of Exploratory Factor Analysis using Principal Component Analysis (PCA) generated two (2) dimensions: Green Behavior and Sustainable Operations.

Tables 2 and 3 underscored the unidimensionality of the constructs by way of determining the base linear combination of indicators through Principal Component Analysis.

The dimension of *Green Behavior* includes setting aside time during meetings to talk about environmental sustainability strategies; development of an operation plan for promoting environmental-friendly initiatives; expansion of messaging around zero waste and recycling and promoting the same in the community sectors; promotion of staff carpooling by choosing public transport preferably e-jeeps, and use of a bicycle in congested and heavy traffic areas; establishment of secure video/web Group conferencing capabilities at all main sites to reduce travel; establishment of green policing network among stakeholders and the community to increase information sharing and foster environmental leadership.; usage of fleet card for monthly fuel consumption to control fuel and maintenance expenses; and the requirement for external stakeholders to electronically submit documents and accept paperless transactions.

Table 2. Dimension on Green Behavior and Its Indicators

Indicators	Value	Dimension
Allot time at meetings to discuss environmental sustainability measures	.822	Green Behavior
Develop an operation plan for promoting environmental-friendly initiatives	.808	
Expand messaging around zero waste and recycling and promote the same in the community sectors	.720	
Encourage staff carpooling, choose public transport preferably e-jeeps, and use of bicycle in congested and heavy traffic areas	.852	
Establish secure video/web Group conferencing capability in all major facilities to reduce travel	.760	
Establish a green policing network among stakeholders and the community to enhance knowledge-sharing and promote environmental leadership	.672	
Use of fleet card for monthly fuel consumption to control fuel and maintenance expenses	.693	
Require external stakeholders to submit documents electronically and accept no paper copies	.599	

Table 3. Dimension on Sustainable Operations and Its Indicators

Indicators	Value	Dimension
Implement Intensified Cleanliness Policy in the station and police-community outpost	.730	Sustainable Operations
Continue to support the DENR National Greening Program and environmental awareness campaigns like afforestation, planting of trees, and gardening, and adopt a forest program	.743	
Implement paper use reductions (paperless) such as records digitization and use of electronic approvals for administrative matters	.730	
Implement bring-your-own-mug and bring-your-own-container programs	.689	
Implement a police uniform recycling program	.579	
Install on-site composting bins in community gardens	.733	
Follow the 3R's concept (Reduce, Reuse, Recycle)	.843	
Upgrade the 3R's concept to 5R's (addition of Refuse and Repurpose)	.830	
Organize Green Audits and use electricity and water resources judiciously in compliance with RA 11285 or the Energy Efficiency and Conservation (EEC) Act	.772	
Buy and promote the use of reusable paper utensils, water bottles, cloth or cotton mesh bags (eco-bag), and other eco-friendly products and ensure single-use items are biodegradable	.744	
Use of renewable resources like solar panels or solar-generated lamps	.620	
Enforce environmental laws by apprehending violators in coordination with the DENR's law enforcers	.838	
Continues to enhance environmental performance in conformance to ISO 14001:2015 or the Environmental Management System (EMS)	.795	

Green behavior encompasses the promotion of sustainability awareness, education of staff on best practices, and advocacy for sustainability in everyday behaviors. It is also about elevating the profile of sustainability and fostering a green culture. Individual choices have varying degrees of relevance when it comes to environmental sustainability. By organizing options such that the greenest alternatives are the default, police stations may essentially assist raise awareness about the benefits of ecologically friendly choices (Konyk, 2018).

Sustainable operations as another dimension covers the implementation of Intensified Cleanliness Policy in the station and police community outpost; continuance of support to the DENR National Greening Program and environmental awareness campaigns like afforestation, planting of trees and gardening and adopt a forest program; implementation of paper use reductions (paperless) such as records digitization and use of electronic approvals for administrative matters, bring-your-own-mug and bring-your-own-container programs, and police uniform recycling program; installation of on-site composting bins in community gardens; abidance on the 3R's concept (Reduce, Reuse, Recycle) and upgrading it to 5R's (addition of Refuse and Repurpose); organization of Green Audits and use electricity and water resources judiciously in compliance with RA 11285 or the Energy Efficiency and Conservation (EEC) Act; buying and promotion on the use reusable paper utensils, water bottles, cloth or cotton mesh bag (ecobag) and other eco-friendly products and ensure single-use items are biodegradable; use of renewable resources like solar panels or solar-generated lamps; enforcement of environmental laws by apprehending violators in coordination with the DENR's law enforcers; and continuous enhancement of environmental

performance in conformance to ISO 14001:2015 or the Environmental Management System (EMS).
Sustainable operations underpin the organizational and administrative activities that police stations conduct to improve the environmental sustainability of their internal and external operations. These measures are concentrated in incorporating sustainability into everyday routines – from fostering sustainable projects like community gardens to knowledge-sharing, advocating green policing, and enforcing environmental laws (Bovornkijprasert & Rawang, 2016; Konyk, 2018).

Conclusion

As established by the results and findings of the study, Green Behavior and Sustainable Operations are the two (2) dimensions yielded through Exploratory Factor Analysis utilizing Principal Component Analysis (PCA). Green behavior entails elevating the importance of sustainability and promoting a green culture through the promotion of sustainability awareness, employee education on best practices, and advocacy for sustainability in everyday actions while sustainable operations serve as the foundation for the organizational and administrative initiatives undertaken by the public safety sectors to improve the environmental sustainability of their internal and external operations.
The explored constructs and dimensions of environmental sustainability in the context of public safety behooves to establish a standard framework of Green Policing as a prospect strategy toward sustainability. Through this, public safety sectors particularly the law enforcers will be urged to prioritize sustainable choices and incorporate sustainability into their daily police operations and routines. More crucially, public safety sectors may take important efforts toward greening their operations by raising their awareness and understanding on environmental sustainability and making the smartest and greenest decision the default option.

Contribution/Originality

This research contributes to the breadth of knowledge by providing empirical data and results on the explored constructs and dimensions of environmental sustainability specifically within the bounds of public safety. As an outcome of my independent and original work, I duly acknowledge all the sources from which the ideas have been derived.

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RESEARCH ARTICLE

Assessment of Rural Transportation in Abi Local Government Area, Cross River State, Nigeria

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Abstract
Generally, the survival of regions and locations is predicated among others, on the corridors of accessibility. In contemporary times, transportation is regarded as the lifewire of development and a lot is dependent on it. In spite of its importance, there is neglect in the development and maintenance of rural transportation system especially in countries of the developing world such as Nigeria. Based on this assertion, this paper seeks to assess the level of service of rural transportation in Abi Local Government Area of Cross River State. The study specifically sought to identify the various modes and means of transportation in the study area, examine the contributions of rural transportation to the socio-economic development of the area, identify the problems militating against effective rural transportation services and make recommendations for improvement. The study relied on questionnaire, interviews and observations for data collection. A total of 400 copies of questionnaire were distributed and 377 copies were retrieved and used for analysis. The study used tables, charts and simple percentages for data presentation and analysis. The hypothesis that was formulated was tested using simple linear regression. The study observed that motorcycle is the most preferred mode of transportation by respondents in the study area. The result of the hypothesis showed that the level of service of rural transportation does not have significant effect on the socio-economic development of the area. This imply that socio-economic development in the study area is not completely tied to the level of service of rural transportation. Furthermore, the problems militating against effective rural transportation services include poor funding and difficult terrain. The study suggested that funding for road rehabilitation be increased by the government and other sources of funding such as Public Private Partnerships be advocated in the road development/rehabilitation process.

Keywords: Transportation; rural transportation; mode of transportation; means of transportation; level of service

Introduction

Transportation is the movement of people and goods from one place to another. Aderamo and Magaji (2010) asserts that transportation plays an important role in the political, economic and social development of any society and whether in rural or urban societies. Transportation constitutes the main avenue through which different parts of the society are linked together. It is the only means through which places and regions are linked together. However, transportation is indispensable to economic development especially in a developing country like Nigeria. This is because transport is essential in the execution of daily economic and social activities in any given area (Akangbe, Oloruntoba, Achem and Komolafe, 2013).

In Nigeria, rural areas have been considered as the major producers of food and fiber for the urban areas. This implies that rural areas are characterized by increased agricultural activities. Akangbe *et al.* (2013) explained that agriculture is the primary and biggest source of income in rural communities and provides employment to approximately 70 percent of its population. Hill (2008) opined that a significant proportion of agricultural task involves moving equipment and materials from one place to another in a wide variety of types and sizes of loads to be moved over different distances and types of terrain. This therefore makes rural transportation a subject of interest (Okoko, 2011).

Transportation demand both modes and means for proper functioning. Therefore, several means of transportation exist for both people and goods. These means have evolved

through the length of time of man's existence on the planet (Mamun and Paul, 2017). The means for transporting people, goods and services include air, water and land. Among the transportation means listed above, the commonest is land/road transportation (Tunde and Adeniyi, 2012). Road transportation is the movement of goods and people from one place to another on land. However, it is the predominant means of transportation mostly, in rural areas (Usman, 2014).

Describing transportation modes, Usman (2013) noted that for transportation to be effective, the mode through which transportation services are provided has to be defined clearly. For instance, air transportation require modes such as aeroplane, helicopters, jets etc. while canoes, ships, boats etc are used in transporting people, goods and services through water. Ayodele and Babatunde (2015) noted that the modes for land transportation include motor vehicles (cars, lorries, buses, etc.) as well as motorcycles, tricycles and bicycles (otherwise known as Para-transit). Others include the use of animals (camels, donkeys and horses), and animal drawn carts.

While cars, lorries, tricycles and buses may be the predominant mode for intra – city transportation in several major urban areas of Nigeria (especially the state capitals), other urban areas and the rural areas mostly use motorcycles for intra-city transportation and even inter-city when distances are short (Bassey and Eteng, 2021). Usman, (2013) further noted that much of rural travel in Africa is however on foot or through intermediate means of transport (IMT) operating along the local footpaths and tracks. These constitute what Starkey (2005) referred to as "invisible" rural transport, consisting of footpaths, cart, cycle tracks and footbridges.

Rural transportation is determined by a number of factors including the presence of roads, nature of goods transported, income of travelers and so on. However, efficient rural transportation can bring about increase in production. For instance, Yaro, Okon and Bisong (2014) showed that where agricultural products are transported with vehicles such as vans, cars, buses, lorries etc, agricultural production among farmers is likely to be on the increase. Equally, where there are large river bodies; boats, canoes and ships may be used for rendering transportation services.

Abi Local Government Area of Cross River State is predominantly a rural area with agricultural activities being the major employer of labour to the residents due to the fertile land. However, there are commercial and agro-industrial activities all of which require transportation services in order to be effective. As a result, various rural transportation means and modes abound in the Local Government Area (LGA). For instance, residents in riverine areas such as Itigidi and Ediba, widely use boats and canoes for transportation while motorcycles, cars, buses, vans, bicycles, carts etc are used for the conveyance of goods and services by others residing and doing businesses in areas that can only be accessible by land. Where bridges are constructed across rivers, both water and road transportation modes are used to facilitate mobility. Examples include Ediba and Itigidi. With the above observation, it is clear that transportation in rural areas of Abi LGA is through different modes and means. Therefore, it was necessary to carry out a study of this nature to carefully assess rural transportation in Abi Local Government Area of Cross River State with particular reference to assessing the level of service.

Literature Review

Concept of Rural Transportation

Rural transportation is the movement of goods, services and people from one place to another within a geographical space called rural. Rural areas in Nigeria simply refer to settlements with population of below 20,000 (Laah, Adefila and Yusuf, 2014). The above definition may not be applicable in other countries like the United States of America, France, England and Russia. For instance, a population of 10,000 people and above constitute an urban area in USA.

Rural transportation system is the culmination of the totality of the different means and modes through which movement is carried out in rural areas. Usman (2014) remarked that rural transport system consists of transport infrastructure, transport operations (services) and the transport users within the rural areas. These include the commercial services and those provided by private owners. Therefore, for any transport system to function effectively, there must exist the appropriate infrastructure, transport services, maintenance and traffic management (Asian Development Bank, 2007). The infrastructure includes the road network, tracks, paths and bridges (including footbridges only suitable for pedestrian and Intermediate Means of Transportation).

Rural transportation therefore represents conscious attempts and strategies towards ensuring that goods, services and people can travel to and from rural areas for business, leisure, tourism etc (Usman, 2014). In simple terms, rural transportation refers to the movement of goods, services and people within the rural areas. Ajayi (2009) explained that the major transportation in rural areas mostly has to do with the conveyance of farm products and other commodities from places of production to where there are needed. The concept of rural transportation is focused on describing the whole procedures, services and humans that are moving within the rural areas. Rural transportation is a key factor in improving agricultural development all over the world (Mamun and Paul, 2014). This is because rural areas (mostly in sub-Saharan Africa) are the major producers of agricultural produce for the urban areas and other places.

In several rural areas in Nigeria, the basic modes through which goods, services and people are moved from place to place include trekking, the use of motorcycles, bicycles, canoes, boats and cars. However, the means of transportation are land, water and air. Of all the transportation means, the commonest used means is land transportation. Among other reasons for preferring land transportation; it is flexible and provides door to door services. In the rural areas, most communities use both water and land transportation to access their farmlands.

The Modes and Means of Transportation in Rural Areas

The means and modes through which rural residents transport people, goods and services across rural areas of the world have been documented. Basically, available literatures have identified that in developing nations, several rural transportation means and modes combine to make rural living meaningful. In New Zealand; Reeder, Chalmers and Langley (2006) observed that people in rural areas are transported through motorcycles, cars and canoes. Others trek and use bicycles in moving within rural areas. Reeder *et al.*,(2006) also noted that car ownership is relatively high and as such, over 70 percent of the rural residents are car owners. Also, in areas with water bodies, modes such as ships, canoes and boats are predominantly used.

In Indonesia, Hartoyo (2013) observed that cars, lorries, vans and buses are largely used for the transportation of people, goods and people in the rural areas and country sides. This is largely because the roads are accessible and are in good condition. He specifically noted that the use of such transportation modes have vehemently increased production among the rural people in Indonesia. Also, in riverine areas, goods, services and people are transported through canoes and speed boats. He equally noted that agricultural products from farms that are nearby are simply taken home through foot.

In Ghana, Dinye (2013) observed that motorcycles constitute the predominant transportation mode in rural areas. He showed that rural areas are predominantly low income earners and as such, they mostly lack the financial capabilities of purchasing cars for movement within their localities. He revealed that the motorcycles are not only used by private owners in villages but also, there are used for commercial purposes by the people and therefore provide the means of earning livelihoods to transporters. Okoko (2011) noted that in Ghana, farmers largely use foot while transporting their goods and services. Okoko observed that the increasing use of foot and bicycles is as a result of the presence of deplorable state of roads.

In a similar finding, Kassali, Ayanwale, Idowu and Williams (2012) observed in Oyo State, Nigeria that transportation in rural areas is through trekking, use of motorcycles, cars and tricycles. They specifically showed that farmers across rural areas that have accessible roads leading to their farmlands transport their products from farms through motorcycles, cars and tricycles. Kassali *et al.*, (2012) showed that trekking was the most widely mode used by rural residents in Oyo. For instance, they note that farmers and residents in Oyo travelled between 5 and 10km from their villages to farmlands on foot.

Usman (2014) also noted that in rural Kwara - Nigeria, there is a combination of various transportation services to ensure economic development. For instance, he showed that rural residents travel to places of interest in rural areas by foot (trekking), bicycles, motorcycles and carts. A small percentage of the rural residents use cars within the rural areas. Obviously, car owners in rural areas mainly use their cars for private purposes, meaning that motorcycles are the predominant transportation mode for moving people. Loads from farms and other places are transported through foot and wheel barrows. He showed that the reasons behind the increasing use of other modes against commercial cars can also be deduced from the deplorable condition of rural roads in Kwara. He suggested policy options to bring about improvement in transportation including the provision of adequate funds for road construction and rehabilitation, community-oriented approach to rural road development and introduction of interventions that will improve the provision of rural transport services.

Similar observations were made by Bassey and Eteng (2021) in their study in rural Cross River State. Their study noted that rural residents depend principally on the use of motorcycles for movement. They further observed that rural residents even use motorcycle operation as a means of earning livelihoods being that commercial motorcycle operators render such services to passengers. Ther study revealed that commercial motorcycle operation contributes to the development and growth of trading and agricultural activities thus, it is the major mode of transportation. With the observation that motorcycles ease movement as well as provide means for earning livelihoods for rural residents, they suggested that the government should empower the youths in rural areas with motorcycles and grant credit facilities to enable youths purchase their own motorcycles.

Contributions of Rural Transportation to Socio-economic Development

In available literature, rural transportation has been recognized as catalysts to socio-economic development of regions and locations. It has tremendously contributed to the growth of the economy and standardization of the living conditions of rural residents. It should be noted that rural areas are mainly agrarian societies which means that farm produce are generated from farms which require efficient rural transportation system and modes to facilitate delivery.

Tuan and Shimizu (2005) observed that in Vietnam, the use of motorcycle in rural transportation has increased the

number of workers and served as an income generating avenue for operators, while further contributing to revenue generation to the government. For instance, motorcycle owners purchase tickets on periodic basis as well as make necessary registration before being allowed to operate. The registration process contributes to the economic base of the government.

In Malaysia, Sadullah (2006) used multinomial logit model to examine motorcycle ownership and rural transportation and how they contribute to agricultural development. His study shows that monthly household income, car ownership, total number of driving licenses in household and number of household members influenced motorcycle ownership. In the long run, transporters that were involved in delivering services through moving people and goods from place to place were earning reasonable amounts that increase their economic status and also they impact the society with their services.

Hsu and Lin (2007) in Taipei Taiwan investigated both car and motorcycle ownerships with 336 samples using multinomial logit model. The study was based on the assumption that when both car and motorcycle are owned by the same household each will have a relation of substitution. The study concluded that the main reason for motorcycle and a car was not cost, but utility factors. The increase in reliability as well as convenience of a car, increased car ownership between 12% - 29% while it reduces motorcycle ownership.

Lokesha and Mahesha (2016) observed that rural transportation including the use of lorries, cars, carts, motorcycles and so on contribute a lot to ensuring that the socioeconomic lives of rural residents receive a boost. For instance, they noted that when the above and more transportation modes are available, it becomes easy for products to be transported from farm to homes and/or markets. The increase in the options for transporting goods through increasing transportation modes further increases agricultural productivity for the overall benefits of the people. In the long run, the socio-economic lives of the people are improved.

Ndiyo, Bassey and Ibia (2016) noted that rural transportation availability is central to the development of the economy of rural areas. Obviously, most rural areas depend on agricultural production and primary activities for economic sustenance. This will become increasingly impossible to achieve without the availability of transportation services to ensure and facilitate the conveyance of goods and services from places of production to where they can be marketed and/or consumed.

Ogunnowo and Oderinde (2012) studied the linkages among rural transformation, provision of basic infrastructure and agricultural productivity in rural Nigeria with a view to determining how the socio-economic lives of rural residents is enhanced through transportation services. They noted that the transportation services provide the avenue for foods, fibre and other important rural products to be sold to urban areas while making huge profits. The amounts gotten as profits are used for family upkeep among other benefits.

According to Aderamo and Magaji (2010), rural transportation makes it easy for farm lands and towns to be accessed and as such areas with good transportation services are likely to provide their residents with more alternatives to economic survival than the reverse. Gbam (2017) observed that rural transportation is not only necessary in the production of agricultural products but further facilitates marketing of the products. He observed that in rural areas of Plateau State, transportation services helps in creating market for agricultural product and reduces spoilage and wastage of farm products. As a result, productivity is enlarged as farmers do not have fears of whether or not their products would be bought by traders. Gbam further argued that improvement in transportation can encourage farmers to work hard and increase production.

Problems Militating Against Effective Rural Transportation Services

The problems militating against rural transportation services are enormous. For instance the condition of rural transportation infrastructure such as the deplorable state of rural roads and shallow waters constitute problems to rural transportation. Tunde and Adeniyi, (2012) observed that it is difficult to embark on the movement of goods, people and services in the rural areas due to the bad condition of roads in rural areas of Nigeria. They observed that due to the deplorable state of the roads, transporters charge huge amounts as fares while moving goods and people. Usman (2014) also noted that the deplorable state of roads negatively affect movement of agricultural goods as motorists are usually unable to access these roads to the farms and back.

Adedeji, Olafiaji, Omole, Olanibi, and Lukman (2014) observed that due to the poor state of rural roads, motorized transport costs are usually high especially during rainy season, as public transport operators hike their fares because of the increased vehicle running cost occasioned by the prevalent bad road conditions. Similar high fares are demanded when transporting goods from farms to markets or homes. In most occasions, farmers lack adequate finance to offset such bills thus; they prefer cultivating in small quantities. Others use head portage, bicycles, hand drawn carts which are energy consuming and cannot carry bulky loads like vehicles.

Nsa (2016) lamented that the government of Nigeria is doing very little in the aspect of dredging water bodies. As a result of the inability of the government to dredge the water bodies, sophisticated speed boats and electronic canoes cannot be used in the transportation process. Nsa revealed that the shallow nature of the waters also do not

give room for the conveyance of bulky agricultural products as only small capacity canoes and boats can be used for the transportation of goods, people and services from place to place.

Furthermore, terrain to a large extent can determine the development of transportation infrastructure. Ikem (2019) noted that rural areas with difficult terrains are usually relegated in the road infrastructure development of several communities. The reason is because; it would be quite expensive to finance the construction process. However, since the transportation infrastructure is not constructed, residents do not see reasons to purchase vehicles that would be used for transportation. It is in a similar observation that Yaro, Okon and Bisong (2014) showed that inaccessible rural areas convey their products through foot and human energy.

There is also the problem of absence of self-help projects. Against this backdrop, Laah, Adefila and Yusuf (2014) had noted that the citizens of rural areas are not collaborating in the area of developing projects for themselves. Laah *et al.*, (2014) buttressed on this while observing that the residents of rural Plateau State are not having effective partnership with the government in the development of rural road infrastructure for their common good.

Okafor (2011) observed that in rural areas of Enugu, there is relegation by the rural residents in the aspect of collaborating in the areas of developing rural roads, maintaining roads and other transportation infrastructure. Okafor further remarked in areas with transportation infrastructure, the sustenance of the infrastructure has remained a problem due to unwillingness of the community residents to collaborate in rural project maintenance.

However, the inability of the communities to collaborate in the development of projects and their maintenance unveils negative effects of effective use of transportation services. For instance, when the roads are in deplorable conditions, vehicles would likely break down and as such, transporters would be discouraged from offering transportation services. In the long run, there will be shortage of transportation services and the conveyance of goods and people would be difficult.

Materials and Methods

Study Area

Abi Local Government Area is a border Local Government Area located on the Central Senatorial District of Cross River State. It lies between latitude 5°00' and 6°30' North of the Equator and longitude 8°00' and 8°10' East of the Greenwich Meridian (Akpoke, 2015). It is bounded in the North and West by Ebonyi State and on the East and South by Yakurr and Biase Local Government Areas of Cross River State respectively (figure 1). Major communities in Abi LGA include Adadama, Afafanyi, Igonigoni, Igbo Ekureku , Igbo Imabana, Usumutong, Itigidi, Ebom, Ediba, Annong, Itigeve, Egboronyi, Emin Ekpon, Isongiyang. Abi however has a total land mass of 334,53162km2 (Abi Leeds, 2016)

Going by the 1991 National Population Census results, Abi Local Government Area had a population of 78,452 persons (National Population Commission, 1991). Current projection with a growth rate of 2.8 percent put the population at 202,010 persons in 2019. The vegetation of Abi is characterized by mangrove and rainforest ecosystems which forms part of the rich fauna and flora of the state. The Abi soil is predominantly clay in nature. Some areas like, Ediba, Adadama and Igbo Imabana also have a mix of clay and loamy soil. The soil is fertile for agricultural activities and production of crops such as cassava, yam, maize, groundnut and vegetables.

The word Abi is coined from the words; Agbo (A), Bahomono (B) and Igbo Imabana (I). The above clans formed the group of settlements in Abi. The Local Government Area was created on the 21st of September, 1991. It was created from Yakurr Local Government Area and has Itigidi as its Headquarters. Abi people belong to the large heterogonous group of upper Cross River called Ekoi of the Bantusan family (Abi Leeds, 2016). The Abi people speak Bahomono and Agbo languages. The Abi people like all patriarchal societies have a rich cultural heritage, elaborately manifested in their traditional dances, festivals, marriage customs, chieftaincy and age grade system which are highly cherished (Abi Leeds, 2016).

Farming is the predominant socio-economic activity in the study area. Subsistent agriculture is the major practice. Most of the residents in the study area are involved in rice, cassava, maize, yam, cocoa yam, groundnut, vegetables and fruit production. A small percentage of people are engaged in businesses and civil/public service jobs; with artisans also constituting a percentage of the population.

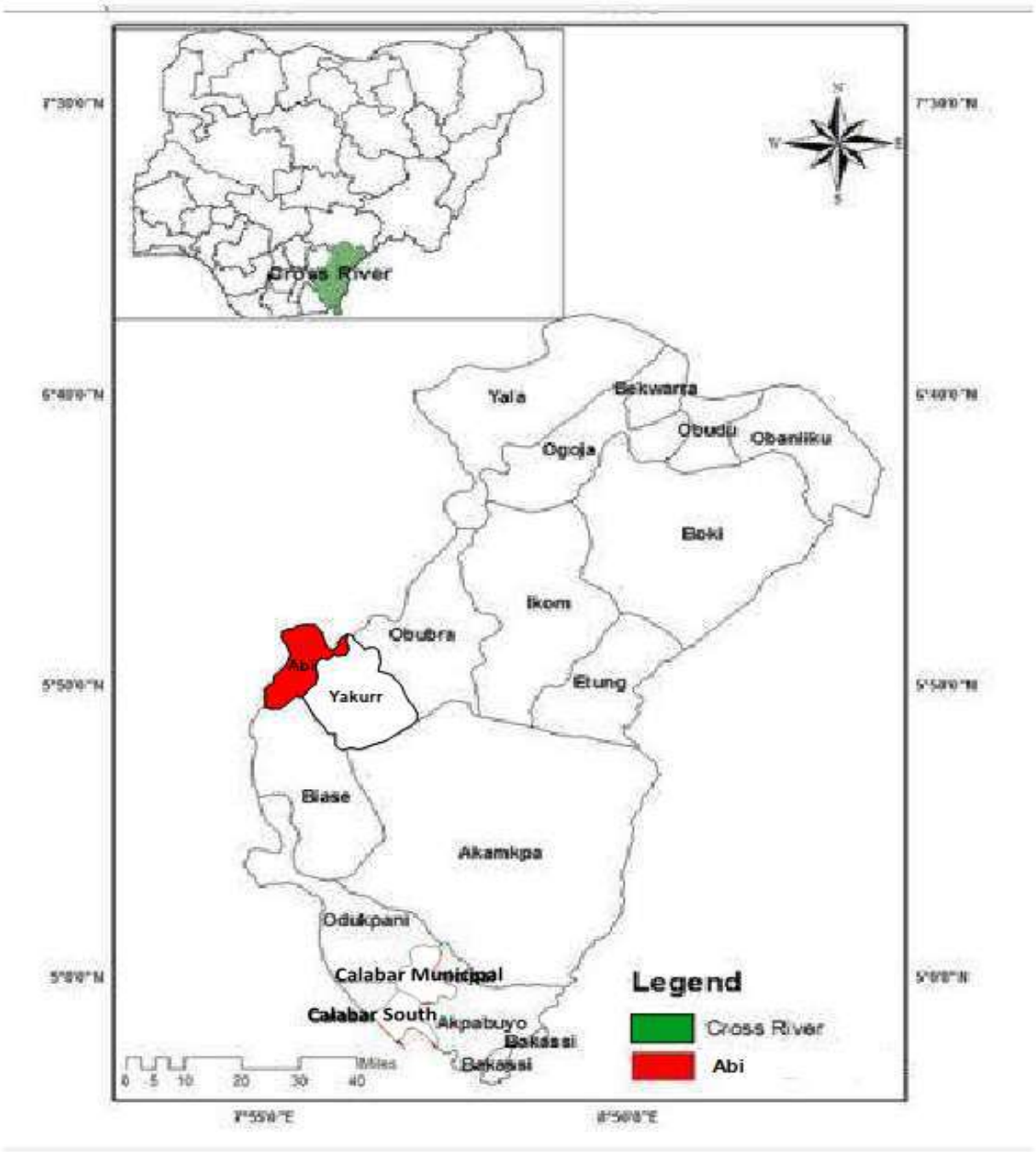

Figure 1: Map of Abi LGA on the Map of Cross River State
Source: Cross River Geographic Information Agency, 2020

Methods

The survey research design was adopted in this study. This required the design of sample questionnaires among others in the collection of data from the target population. The data collected were presented and analyzed in order to draw

inferences**.** The study further employed both primary and secondary data**.** The primary data include age of respondent, sex, occupation, educational qualification, mode of transportation, amount charged by transportation operators, factors determining choice of transportation mode etc. Secondary data were also used. Data from this category include population figure of the study area and maps of Nigeria, Cross River State and Abi LGA. The primary and secondary sources of data were used in the study. The primary sources of data used in this study include the use of questionnaires, direct observation and oral interviews. The secondary sources of data were published documents. These published documents include the 1991 population of Abi LGA which was collected from the National Population Commission Area Office, Calabar, maps from Cross River State Geographic Information Agency. Unpublished documents including past research works and government reports were used. The population of the study according to the 1991 population was 78,452. The population was projected to 2019 and it resulted to 93,085. This number formed the sample frame for the study. In order to determine the sample size, the Taro Yamane formula of infinite population was used as follows.

$$n = \frac{N}{1+N(e)^2}$$

Where;

n = Sample Size

N = Finite Population

e = Level of Significance (Limit of tolerable error =0.05)

$$n = \frac{93,085}{1+ 93,085(0.05)^2}$$

$$n \frac{93,085}{1 + 93,085X 0.0025}$$

$$n = \frac{93,085}{232.7125}$$

n =400

Therefore the sample size for the study was 400.

The stratified random sampling method was adopted in the collection of data from the field. In the light of the above, Abi LGA was divided into three (3) units. The units were divided using the three major clans that make up the entire Abi LGA. There are; Agbo, Bahomono and Igbo Imabana clans which were considered as units in the stratification process. From each of the units established above, the researcher randomly selected four communities within each unit for data collection. In Agbo clan, the communities that were studied were Igbo Ekureku, Itigidi, Etani and Adadama. In Igbo Imabana clan, the communities studied were Ikpalegwa, Lehangha, Ebol and Ilike. In Bahomono clan, the communities studied were Anong, Ediba, Abeugo and Afafanyi. The systematic approach was used in distributing the questionnaire to the individual communities as shown in Table 1. Copies of questionnaire were the major instrument for data collection. Specifically, a total of 400 copies of questionnaires were administered in the study area. Table 3.1 shows the number of questionnaires that were administered in each sampled community. The questionnaires were distributed in line with the population of the community. In order to achieve this, the ratio of the sampled neighborhoods were divided by the total ratio of the entire sampled neighborhoods and multiplied by the sample size to arrive at the number of questionnaire distributed in each neighborhood.

Using Egboronyi as an example, it was expressed as:

n =R/TrXS

Where: n = number of questionnaires to be distributed at each unit

R = ratio of the projected population of each unit

Tr = total ratio of the entire sample unit selected

S = sample size

n = 5/78 X 400

n = 27

Data were also obtained through oral interviews with community heads and youth leaders in the study area as well as the Town Planning Authority in Abi Local Government Area. In othertables and charts were used in carrying out the analysis of data that were obtained from the field. The hypothesis was tested using simple linear regression analysis. The hypothesis states that the level of service of rural transportation does not have significant effects on the socio-economic development of the residents in Abi Local Government Area. Statistical Package for Social Science (SPSS) was used in conducting the test. The Multiple Regression Analysis formula is as follows; Y = a + b x + E. Where: Y = dependent variable, X = independent variable, a = intercept, b = slope, E = residual (error)

Results and Discussions

Table 2 revealed that the preferred mode of transporting goods among respondents differ. As seen in the table 209 (55.5 percent) respondents prefer using motorcycle while 13 (3.5 percent) prefer cars. Equally, 13 (3.4 percent) respondents use speed boats for movement within the LGA. The table also showed that 21 (5.6 percent) respondents travel within the LGA with canoes while 134 (35.5 percent) trek within the LGA.

The modes for transporting goods among the respondents in the study area is presented in table 3. The table shows that 138 (36.6 percent) transport goods with motorcycles while 28 (7.4 percent) transport goods within the LGA through cars. The table further revealed that 69 (18.3 percent) transport goods within the LGA through canoes and 8 (2.1 percent) use speed boats. Those that trek with goods were 74 representing 19.6 percent and 60 (16 percent

use wheelbarrows. From the table, it is obvious that those that use motorcycles are more. This equally implies that motorcycles are the most used transportation mode in the study area.

Table 1: Distribution of Questionnaire

S/N	Unit	1991 Population	Projected Population 2019	Ratio	Sample size	Response Rate
	Agbo					
1	Egboronyi	832	1,647	3	15	13
2	Igbo Ekureku	2068	4,481	9	46	43
3	Itigidi	7475	16,198	11	56	49
4	Adadama	6743	14,612			
	Igbo Imabana					
5	Ikpalegwa	1589	3,443	5	26	25
6	Lehanga	744	1,612	2	10	10
7	Ebol	1809	3,920	6	31	29
8	Ilike	2014	4,281	8	41	34
	Bahomono					
9	Anong	1976	4,201	7	36	36
10	Ediba	8936	19,364	12	62	59
11	Abeugo	905	1,961	4	21	19
12	Afafanyi	2531	5,485	10	51	9
Total		31,631	36,531	78	400	377

Source: Statistical Computation, 2019

Table 2: Preferred Mode of Transportation by Respondents

Transportation mode	Frequency	Percentage
Motorcycle	209	55.4
Car	13	3.5
Canoe	21	5.6
Speed boat	13	3.4
Trekking	121	32.1
Total	**377**	**100**

Source: Field Survey, 2020

Table 3: Preferred Mode of Transportation for Goods

Transportation Mode	Frequency	Percentage
Motorcycle	138	36.6
Car	28	7.4
Canoe	69	18.3
Speed boat	8	2.1
Trekking	74	19.6
Wheelbarrow	60	16
Total	**377**	**100**

Source: Field Survey, 2020

Table 4: Level of Service of Transportation

Level	Frequency	Percentage
Excellent	171	45.4
High	112	29.7
Medium	59	15.7
Low	16	4.2
Very low	19	5
Total	**377**	**100**

Source: Field Survey, 2020

The level of service of transportation modes by the respondents was ascertained in table 4. The information in the table revealed that 187 (49.6 percent) respondents were of the view that the service was excellent while 132 (35 percent) said it is high. The table further revealed that 58 (15.4 percent) respondents were of the opinion that it is medium while 16 (4.2 percent) said it is low and 19 (5 percent) said it is very low. From the findings, it was clear that those that depend on transportation modes for their businesses on daily basis were more. This was based on their judgment that the level of service of transportation is excellent and high. By implication, it may be deduced that transportation services are high in the study area.

Table 5: Activity that Attract Transportation Modes

Activity	Frequency	Percentage
Farming	125	33.2
Commercial	198	52.5
Others	54	14.3
Total	**377**	**100**

Source: Field Survey, 2020

The activities that demand the use of transportation modes within the study area by respondents varies. Table 5 shows that 125 (33.2 percent) use various transportation modes for farming purposes while 198(52.5 percent) use them for commercial activities. The responses of 54 (14.3 percent) respondents explained that they depend on transportation modes for other activities such as tourism, recreation and sporting activities.

Table 6: How Rural Transportation Contribute to Economic Development

Contribution	Frequency	Percentage
Employment	133	35.3
Agricultural Expansion	187	49.6
Revenue Generation by Government	39	10.3
Others	18	4.8
Total	**377**	**100**

Source: Field Survey, 2020

Rural transportation is highly beneficial as it provides the means of earning livelihoods as noted in Table 6. Respondents under this category include motorcycle operators, canoe sailors, drivers and wheel barrow pushers. These persons are principally employed by those they offer services and the means of generating funds is dependent on the services they offer. The Table further revealed that 187 (49.6 percent) have been positively effected through the use of transportation modes to the extent that their agricultural practices have been expanded. Also, 39 (10.3 percent) respondents were of the view that the constant and consistent use of transportation modes leads to increase in the revenue that is generated by the government. These revenues come in the aspect of tickets and taxation on commercial operators of transportation modes. Even more, private owners of transportation modes seek for licensing and renewal of documents (when necessary).

Table 7: Level of Socioeconomic Development

Level	Frequency	Percentage
Excellent	126	33.4
High	78	20.7
Medium	99	26.3
Low	56	14.9
Very low	18	4.7
Total	**377**	**100**

Source: Field Survey, 2020

Table 7 explained the level of socioeconomic development in the study area. The study showed that 126 (33.4 percent) respondents agreed that the level of socioeconomic development is excellent due to rural transportation while 78 (20.7 percent) respondents revealed that its high while 99 (26.3 percent) said that the level of socioeconomic development is medium. In the views of 56 (14.9 percent) respondents, the level is low while 18 (4.7 percent) respondents say the level is very low. With this information, it is clear that the residents of the study area are taking advantage of the availability of transportation modes to expand development,

Test of Hypothesis

The hypothesis formulated for the study was tested using simple linear regression analysis. The null hypothesis states that "The level of service of rural transportation does not have significant effect on the socioeconomic development of the residents in Abi Local Government Area". Analysis was based on Statistical Package for Social Sciences (SPSS). The result of the analysis is presented in table 8

Table 8: Model Summary

				Std. Error of the	Change Statistics		
Model	R	R Square	Adjusted R Square	Estimate	R Square Change	F Change	Sig. F Change
1	.234[a]	.055	-.064	53.534	.055	.462	.516

a. Predictors: (Constant), x

The result from the regression test as presented in table 4.15 shows that the calculated significant value was 0.516 which is greater than 0.05. Based on this result, the null hypothesis was accepted and the alternative hypothesis was rejected. This implies that the level of service of rural transportation does not have significant effect on the socioeconomic development of the residents in Abi Local Government Area. This suggest that the totality of the lives of the people of the study area is not basically dependent on the transportation services in the area. Therefore, other activities such as trading, agricultural practices among others may account for the level of socioeconomic development.

Discussion of Findings

The various means and modes of transportation in the study area were identified. It was revealed that the predominant mode of transporting goods within the study area is motorcycle. Other modes equally exist which include cars, canoes and trekking. The reason for the continuous use of motorcycle is the state of the road which is highly deplorable. Obviously, the use of motorcycles above other modes is due to the fact that motorcycles have the ability to be manipulated into roads that are not in very good state. Due to the fact the roads in the study area are not in good conditions, residents of the study area prefer moving within the study area with motorcycles. This observation aligns with the findings of Dinye (2013) who revealed that motorcycles are the predominant transportation mode in rural areas. Dinye noted that rural areas are dominated by low income earners that lack financial capabilities of purchasing cars for movement within their localities. Dinye further revealed that the motorcycles are also used for commercial purposes by the people and therefore provide the means of earning

livelihoods to transporters. However, motorcycles are configured to be manipulated on land therefore, land is largely used as means of transporting people and goods in the study area. Residents in the study area also trek to locations to deliver goods and services. Moreso, the availability of large river bodies in Abi LGA has promoted the use of canoes for transportation within the study area. The result of the hypothesis has shown that socio-economic development in the study area is not completely tied to the level of service of rural transportation. This imply that other variables equally contribute to economic development in the study area. Instance of such variables may include infrastructure availability such as electricity, water and other job opportunities. Nevertheless, rural transportation have contributions only that it is not the sole determinant of socio-economic development in the study area. For instance, the study noted that rural transportation provides residents with the means of earning livelihoods. Notably, through rural transportation, the services of motorcycle operators, canoe sailors, drivers and wheel barrow pushers are employed. Obviously, the funds they generate are used to aid their livelihoods. Equally, transportation contributes to agricultural expansion further revealing in food production at increased level. This is because, energy and travel distances are saved through the use of machines for traveling to farms and markets. This assertion is buttressed by the findings of Hartoyo (2013) who showed that the development of roads in rural Indonesia promoted agricultural practices and ensure food availability. Okoko, (2011) returned that rural transportation in Ghana also promoted agricultural activities in Ghana. Also, transportation contributes to increase in revenue generation by the government in form of vehicle licensing and daily ticket sales to commercial transporters. The problems militating against effective rural transportation services in the study area are poor funding, limiting the regular rehabilitation and upgrading of road. This particular reason has resulted in the presence of deplorable roads and collapsing transportation infrastructure. Another factor is the difficult terrain in the study area which demands large sums for fixing of roads further serving as a discouraging factor for the government to commit funds to road development.

Recommendations

In line with the study objectives and subsequent findings, the following recommendations were made;

i. Since land is the predominant transportation means, the roads in the study area should be rehabilitated regularly.
ii. Residents in the study area should be encouraged with facilities for mobility such as motorcycles, vehicles and wheel barrows so as to encourage productivity among the residents of the people
iii. There is need for diversification of the economy and rehabilitation of more roads within the study area so as to encourage farmers to embark on agricultural productivity.
iv. Funding for road rehabilitation should be increased by the government.
v. Finally, other sources of funding such as Public Private Partnerships should be advocated in the road development/rehabilitation process.

5. **Conclusion**

The study assessed rural transportation in Abi LGA. The study specifically identified the predominant transportation means and modes that are used for rural transportation in the study area. The study identified that land is the main transportation means that the residents of Abi LGA travel within the LGA. Transportation modes used by the residents include motorcycles, cars, wheel barrows and others trek. As seen in the study area, rural transportation contributes to the development of socio-economic activities, yet, socio-economic development is not completely tied to the level of service of transportation in the study area. This is because some of the residents do not mainly use machines for movement.

Finally, rural transportation in the area is plagued with problems. The problems basically include weak funding by relevant authorities and weak monitoring/supervision in the road development/rehabilitation process.

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RESEARCH ARTICLE

Health Performance Empirical Evaluation on Urban Housing Floods in Odosida, Ondo city, Nigeria

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Abstract
Natural occurrence of streams, rivers and flowing water attract emergence of urban housing along river bank is to tap water for domestic, irrigation, industrial use; deposition of minerals and nutrients for agricultural purpose. Consequences caused by recent events of floods in the urban centers are not limited to socio-economic, environmental loss but also increase in health challenges with loss of life. Flood itself cannot be held responsible for the catastrophe but the activities of people, society and urban housing encroaching on natural space of lowland, wetland, prone areas, also; landscape reshape to reclaim beaches by cutting off hills fosters thereafter, destruction of life and property. The study therefore identified the consequences of urban housing flood in three areas. Quantitative method including frequency tables, histograms, pairwise ranking, chi-square and analysis of variance (ANOVA) were also used to interpret the data collected. The result shows that disease occurrence is significant to urban housing flood; correlation between flood and marginalization to adequate housing quality; and floods is significant to urban housing development. It is clear that vulnerable and flooded prone milieu is mostly occupied by urban poor because of inability to avoid good housing quality and there is high of cases of cholera, malarial, water-borne, measles among residents in the study area. Society is becoming more aware that floods can be controlled to a limited extent; hence, safety against floods must be sought for, to prevent loss of life, properties and socio-economic investment. This paper recommends absolute delineation from vulnerable area, government and property developers should ensure good housing quality, total relocation of urban housing from marginal land and compensation to victims. Studies on comparative evaluation of urban housing vulnerability to flood on highland and lowland; environmental disruption of urban housing in lowland require additional investigation.

Keywords: health performance; safety; vulnerable milieu; urban housing floods; disasters; diseases

Introduction

Natural disasters have caused significant damages to both natural and man-made milieu in recent times. Hence, such hazards are caused majorly by natural forces which include earthquake, tsunami, tornado, landslide, wave and greenhouse effect, land submergence, typhoons/hurricanes/willy-willies, smog and among others (Ogunbodede and Sunmola, 2014). Not only but also flood which is surface water covering a previously dry area. Flood is a destructive water-related hazard and is mainly responsible for the loss of human lives, infrastructure damages and economic losses (Ogunbodede and Sunmola, 2014; Ogundeji and Fadairo, 2018; Fadairo and Ganiyi, 2012). Urban flooding generation is caused by natural multifactorial mechanisms such as geomorphological (the formation and structure of the Earth surface such as texture and type of soil, rock), physiographic (the natural features of the earth's surface such as topography) and climatic conditions (rainfall, humidity, precipitation) all affecting the hydrological (the properties, distribution, use, and circulation of the water on Earth and in the atmosphere) processes, the generation of floods and in addition to negative impact of urbanization growth in recent time (Fadairo, 2013; Basorun and Fadairo, 2012; Amao, F. L., 2012; Ogundeji and Fadairo, 2018; Onibokun, 1972). Recently, there are numerous studies on mitigation to flood damage due to record of an increase in its frequency, magnitude, and intensity (Douglas et al., 2010; Pitt, 2008).

Also, Studies have shown that natural causes of flood can only be reduced to minimal effect in as much as rainfall, coastal, low land or flooded prone area and other natural element would be difficult to adjure. Aside the natural sources of flooding such as heavy, prolonged rainfalls and bank overflows, there are anthropogenic (relating to or resulting from the influence of humans on the natural world) causal factors of flooding (Taiwo, O. J., Agbola, B. S., Ajayi, O. and Wahab, B. W., 2012). This paper investigates the inevitable existences of lowland areas within the urban centres and health associated prevalent diseases. Aside intense rainfall events that generate flash floods, the man made effect and activities on the earth surface such as tillage and deforestation in the rural, also increase's in concrete constructions and pavements in the urban centres. It is a clear statement that vulnerable and flooded prone milieu is mostly occupied by urban poor because of inability to avoid good housing quality, the study area shows that the features of prescience had made the occupier to abandoned and relocated to high or non-prone area.

At a time, dwellings were typically constructed on higher land, while lower grounds were used for farming. Riparian peoples benefited from floods sediment which enriched the soil with nutrient and irrigation for agriculture. Hence, people lived in harmony with floods (Kundzewicz et al., 2014) in the past. The frequency and consequences of extreme flood events have increased worldwide. The key impetus for these increase are the world's population growth, the increase in socioeconomic activities in flood-prone areas and significant climate change, which occurred in almost all countries of the world (Ogundeji &Fadairo, 2018; Bouwer et al., 2017). On the other hand, the steady growth of impervious surfaces and reduction of forestation increases floods. Moreover, the exponential increase in development, expansion of urban areas to nearby rivers and encroachment to river path or prone area exacerbate flooding and simultaneously increases the impact (Nardi, F., Annis, A., Biscarini, C., 2018; Samela, C., Albano, R., Sole, A. and Manfreda, S., 2018).

Therefore, there is a need for strategic applications basically to "control human influences on floods occurrence" and also to evaluate the impact of such events. Hence, the research area is the human influences which are construction of housing and its subordinate amenities which covered suppose forested land usually through which amount of water percolate is disavowed in the urban centers. The accumulation of this water together with the sewage from these homes becomes a treat that yield to flooding. The activities of man on the natural surface that are attributed to flooding includes roofs, pavements, roads, concrete works, bridge constructions, dams, wastes, sidewalks, parking lots (Kundzewicz, 2004), extensive asphalted or concrete landscape, drainage, coastal or river path backfilling (beach reclaiming), irrigations and or rechanneling of river path, urban housing and building construction are among other influences.

Statement of problems

Flooding has become a common feature in Nigeria not only in the low-lying coastal areas but also in the hinterland as well as the wetland regions (Ogunbodede and Sunmola, 2014). The population growth and urbanization activities have exerted pressure on available marginal and flood prone lands to the extent that a larger proportion of lowland and river basins have been encroached by people (Ogundeji and Fadairo, 2018). These activities on such encroachment include housing and its adjoining amenities which include poor drainage system, pavement that reduces infiltration, discriminative refuse disposal and with blockage of water path. The results of such man influence amount to surface water and floods effect. Water is universal solvent. Hence, floods deteriorate if not damage both man-made (bridge, roads, houses and other urban structures) and natural structures (loose soil, contaminate drinking water, destroy greenery). Man also extend marginal milieu to usable territories, Ogunbodede and Sunmola (2014) explain that urbanites reshaped both natural and cultural landscapes by leveling off hilly areas to fill valleys, reclaiming beaches, wetlands and hinterland (a case study of Leki community in Lagos, Nigeria) into usable business ventures; thus, making large areas of artificial land in the urban environment and simultaneously with erection of different magnitude of urban structures occupying this new land irrespective of whether such lands have the capacity to retard inflow of water or not. Aside recorded economic impact, Oriola (2000) and Sewel (1969) also confirmed the environmental damage induced by man's exploitation.

Research question

From the foregoing objectives, these research questions are pertinent:

1. What are the causes of urban housing flood in the area?
2. Is marginalization to adequate housing quality also contributed to urban housing flood?
3. Does impervious feature of urban housing have effect on flood intensity and magnitude?
4. What are prevalent illness experiences by the respondents in urban housing flood milieu?

Aim

This paper aim at identifying health effect with level of productivity against urban housing floods in the lowland of Odosida in Ondo city.

Objectives

The specific objectives are to;

i. Examine the general causes of urban housing flood in Odosida area.
ii. Assess lowland (prone) area within the urban centres and its vulnerability to floods
iii. Evaluate the increase in development, expansion of urban areas and other anthropogenic (activity of man) factors and its significance to excessive floods.
iv. Evaluate effect of floods on human health.

Research hypothesis

In line with the research question 3 and 4 of this work, the following hypotheses are postulated:

H_0: Disastrous Flood is significant to urban housing development
H_1: Flood disastrous is not significant to urban housing development

H_0: The average diseases occurrence (mean) is the same. That is, the disease occurrence is significant to urban housing flood within the study area.
H_1: The average diseases occurrence (mean) is not the same. That is, the disease occurrence is not significant to urban housing flood within the study area.

Background to the study

Urbanization is basically continued growth of urban centre, swelling and increase in population concentration in the city (Bakare, 2017). Urbanization is fast impacting its negative consequences on most of the cities as a result of rapid urban development/land use change in the form of massive road/building construction, removal of soil surface for infrastructure purposes, drainage/canal construction, deforestation and soil surface pavement (Ogundeji and Fadiro, 2018), altogether have increased the runoff in addition to rainfall and snowmelt, thereby increases the risk of flooding in the cities (USGS, 2011; Nirupama and Simonovic, 2006).

As urban population comes to represent the larger proportion of the world population likewise urban floods will account for an increasing part of total flood impact (Jha, Robin and Jessica, 2012), hence the urgent need to examine the circumstances surrounding flood disaster cannot be over-emphasized. Bakare (2017) explained that devastating urban areas, unplanned development in floodplains, ageing drainage infrastructure, increased paving of soil surface and other impermeable surfaces, with lack of flood risk reduction activities contribute to flood disaster impacts (Jha, et al, 2012).

Housing quality in the survey area

Lowland area in Odosida is experiencing poor housing quality, deplorable basic facilities, high level of housing deterioration, as well as growing incidence of slum due to an increase in surface water for long period of time. The dwellers built home not only on the high land but also on the available low land as a result of urban expansion without a fore knowledge of the future treat. The study shows that low-income earners are the dominant and house owner of the environment. Most of the occupants narrated that the land were allocated to them in the period of dry season and only to discovered that the land is at the receiving end for surface and running water from the whole Odosida community.

Housing problems in Nigeria

Developing countries are characterized with an uncontrollable growth of the urban population often caused by lack or poor infrastructural amenities and poor economic conditions in the rural areas has opined by Ogundeji and Fadiro (2018). The proportion of the Nigerian population dwelling in urban centres has increased from 7% in 1930s, 10% in 1950, 20% in 1970, and 27% in 1980 to 35% in 1990 (Okupe, 2002). There is occurrence of overcrowding on existing housing, rural-urban drift that has caused squatter settlements in cities with 60% of Nigerians houseless (Ogundeji and Fadiro, 2018; Olayiwola, 2012; Federal Government of Nigeria, 2004). Majority of the houses is also constructed with second-hand materials, build on illegal land (Adeyeni, 2015), marginal or flood prone area (Ogundeji and Fadiro, 2018). They are badly maintained and lack the basic necessities of life like sanitary facilities, light, air and privacy (Agbola, 1998). Researchers on housing studies conclude that urban centres in the country are characterized by high-density buildings, sanitary problems, air pollution, surface water, noise and solid wastes (Filani, 1987; Agbola, 1998). Olotuah (2002) estimate 2.3 million urban dwelling units to be substandard, 33% of urban houses considered to be physically sound while 44% and 19% require minor and major repairs respectively to bring them to normative.

Thomas (2017) specifically discusses housing problems in Nigeria under the following sub-headings; Housing finance problem, Low housing investment, High cost of houses and rent, Inadequate access to buildable land, Mismatch in Housing Goal and Real Achievement, and Building materials problems.

Housing Finance Problem - Nubi (2008) narrates the popular method of housing finances in Nigeria which are through personal savings, loans from friends, relatives, commercial banks and other mortgage institution. These sources are no longer assuring and sustainable especially

for the low income earners and the inflation rate in Nigeria (Agbola, 1998) for procurement of land, material, wages and building services bills.

Low Housing Investments -According to the 1996 Nigerian national report of the Habitat II conference, the level of housing investment as a proportion of GDP in Ibadan and Kano was low as 5.9% and 28.41% respectively and resulted from housing being a long-term low profit yielding investment when compared to other short-term fast profit such as manufacturing and transport (Agbola, 1998). In addition, limited access with high-interest rates on housing loan partly characterized the problem of low investment in Nigeria (Olayiwola, 2012).

High Costs of Houses and Rent - The combined problems of finance, rising costs of building materials and low housing investment have brought about housing shortages. For instance, the unit price of a three-bedroom bungalow (Bakasi type) built by the Federal Housing Authority in Abuja increased from #l.65 million in 1998 to about #3.5million in the year 2003 and about 10.8million in year 2012 (Thomas, 2017).

Inadequate Access to Buildable Land - Lands in prime locations in the urban centres are beyond the reach of low and medium income households in Nigeria (Thomas, 2017) prior to the promulgation of the land Use Decree No.33 of 1978 where land allocation was vested in the Governor or the local government Chairman (Okupe, 2002) compare to Adeleye (2012) enunciation on traditional land tenure system which was with ease.

Mismatch in Housing Goal and Real Achievement - Thomas (2017) opined one major problem of adequate housing in Nigeria is the mismatch between housing goal and real achievement which were marred by low pace of construction, high costs of building materials, budgetary shortfalls, poor coordination, use of unrealistic standards and problems of land acquisition.

Building Material Problem - Olotuah (2006) explained the efforts to boost local production by the Nigerian Building and Road Research Institute (NBRRI) established in 1978 for that purpose has not achieved much. The high cost of foreign building materials is one of the major problems militating against adequate housing supply (Onibokun, 1986; Agbola and Onibokun, 1990; Agbola, 1993; 1998).

Characteristics of coastal areas housing

Their local topography limited the amount of land suitable for development and as such put land prices at a premium (McLean and Shen, 2006). Physical isolation of wetland, lowland and coastal towns has been often a significant barrier to economic growth, development and regeneration (Thontteh, 2014). However, complete relocation could be the best solution as regeneration would not be enough to reduce effect of flooding.

Floods growth and its effect

Floods are the most common natural disasters and represent 40% of all natural disasters between years 1985-2009 (Soukopová and Furová, 2012). Also, Kundzewicz (2004) affirmed that floods have killed annually on average more than 12,700 people worldwide, affected 60 million others and caused 3.2 million people to become homeless (Kundzewicz, 2004). UNICEF (2022) acknowledged that since September 2022, worst floods in a decade affected 2.8 million people of which an estimated 60 percent are children across 34 of the 36 states in Nigeria with over 1.3 million and 600 people displaced and have died respectively in relation to flooding. Thus, increases the attention of researchers to the consequences of floods and measures that could be developed to reduce economic effects (loss) of flood (Munich, 2005). Studies explained that flood-prone areas were initially attractive for socioeconomic activities through provision of water resources for domestic purpose, irrigation, industrial use, minerals and nutrients for agricultural production which also encourages urban development (Smith and Ward, 1998). Increasingly number of housing in the urban vulnerable centers also increases the number of casualties. Aside the deduced socio-economic losses by many researchers (Ogundeji and Fadairo, 2018), there is need to put an end to poor health and loss of lives which cannot be quantified. Bangladesh and China have recorded at least 2,5 million fatalities in the last 100 years in major floods which has drastically reduces human production and inversely reduces the economic output of a country. The nature cannot be held responsible for floods and it harmful effect, but the people, society and the urban housing taken natural space from water and put themselves in her way (MŽP SR, 2010). The flood as a natural hazard has effect on the stability of society. If more urban housing, society and people are to dwell in vulnerable areas with more businesses to settle down in these areas, then the more intensive effect a flood event will have upon society (Seifert, 2012). Damage to infrastructural lifelines in the community includes water supply, sewerage and drainage, gas and power supply, telecommunication, roads and railways. Hospitals, schools and fire brigades are essential facilities that got damage too. However, direct damage (costs for repair, replacement of damage facilities, equipment) and indirect damage (loss of revenue by the network operator, delay costs) to the affected structures are the reciprocal loss. (Dutta et al., 2003; Scawthron et al., 2006).

Background information about the study area

The physical geography of the area, apart from communities located in the upland are plain, all other communities fall within the lowland because of its proximity to Core Business District (CBD) and its economic advantages. The lowland consists of rivers, creeks, estuaries and stagnant swamp covers. The region falls within the 'tropical wet and dry climate which range between March and October and dry season comes between November and February respectively with mean annual rainfall of about 1615mm. The annual mean temperature is 27°C, with a maximum of 30°C. Ondo town is the most populated city in Ondo state after Akure and with 113,900 during the 1991 population census, located on latitude 06°30'N and longitude 04°45'E. The town is bounded on the north by Ile-Oluji/Okeigbo local government area and on the east by Idanre local government area why on the south-west is Odigbo local government area (Ogundeji and Fadairo, 2018). Identification of three different points after reconnaissance survey of Odosida area that are lowland are flooded, often resulted to disruption of transportation, communication, structural damage to buildings and loss of lives and properties.

Research methodology

Purposive sampling method was used to sample three areas namely Adeyemi College of Education (ACE), Christ Apostolic Church (CAC, Oke-Iye) and University of Medical Science (Unimed Campus) of Odosida Community in Ondo city for information collection. They were wetland and lowland regions that are vulnerable to flooding. Administration of questionnaire to residents to deduct their socio-economic profile, sex, age, distribution, nature of the environment, waste disposal methods in the environment, causes of flood in the milieu, consequences of flood particularly reference to health challenges and solutions to floods in the environment. The interview was successful because of the help from the community chairman and the youth leader in the area. A total of one hundred and fifty (150) respondents were interviewed from the study area. Data collected were summarized and stored in statistical tables and charts. These also include frequency distribution tables and histogram. Relevant mathematical and statistical techniques were used where appropriate for the analysis.

Results and discussions

The physical environment suffers destruction of vegetation, washing away of top soil and water pollution, displacement of wildlife from their natural habitat due to activities that accompany urbanization in the recent times. One of this activities of urbanization is construction of housing and it amenities that has disrupted the natural surface of the earth crust through excavation, removal of surface soil, diversion of river path, filling up of beach, lowland and lagoon. The aftermath of such activities among others aided the magnitude, intensity and rate of water that ought to have found its way through natural means of "percolation, waterlogged and runoff" but interrupted. Hence, rapid urbanization increases number of roof, housing and pavement in the urban center and thereafter reduces rate or amount of water to be percolated. Also, an encroachment of structures in waterlogged area and obstruction of water runoff path amount to flooding. Fishing, irrigation, deposit of fertile soil for agriculture are among the positive effect associated with urban housing flood and the negative impact include dampness, destruction of properties, lives and land use changes which invariably affect socio-economic, health and environmental dilapidation respectively as a result of alterations to the natural environment.

Socio-Economic characteristics of respondents

The following indicators; income, health, education, occupation and buildings condition were considered to ascertain level of effect of urban housing floods in the environment. Table 1 and Figure 1 shows 62% males and 38% females were interviewed thus; majority respondents are male over female which is a reflection of female marginalization to access housing facility and legal land (Bako, 2012). This experience is a violation of human right and contributes to women's increasing poverty (UNCHS, 1985).

Table 1: Sex distribution of the respondents

Sex	Opp. ACE	CAC Oke- Iye	Unimed Campus	Total	(%)
Male	30	37	26	93	62
Female	20	13	24	57	38
Total	50	50	50	150	100

Source, Author's archive

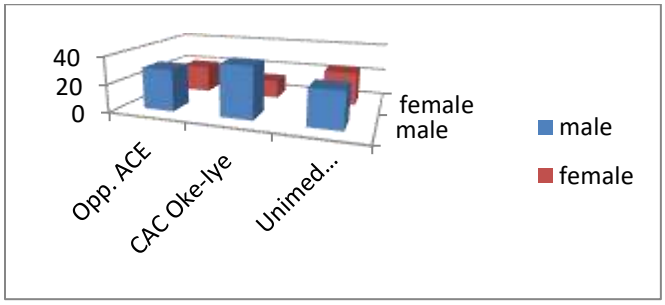

Figure 1: Sex distributions of respondents
Source: Author's archive

The age distribution of the respondents shows that large number of population comprises youth ranging from; less than 30 years to 40 years of age are residing in the study area as shown in the Table 2 and Figure 2. Hence, requires

adequate accommodation to increase youth productivity being the active population and for economic growth in the urban center.

Table 2: Age distribution of the respondents

Age	Opp. ACE	CAC Oke- Iye	Unimed Campus	Total	(%)
Below 30	21	4	18	43	29
31-40	15	5	12	32	21
41-50	11	24	10	45	30
51-60	3	10	5	18	12
Above 61	0	7	5	12	8
Total	50	50	50	150	100

Source: Author's archive

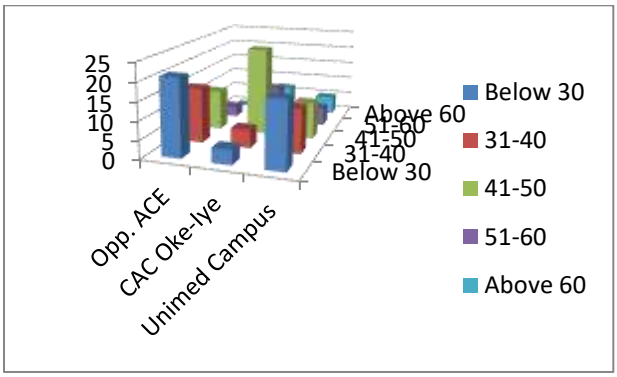

Figure 2: Age distribution of respondents
Source: Author's archive

Data on respondents' occupation shows that 40% are civil servants which means 60% of the respondents are not gainfully employed which is a major cause of poverty influence on the respondents to occupied available, avoidable urban lowland area and simultaneously prone to flood. Job opportunities at Unimed, ACE, Wesley University, General Hospital, and Trauma Centre among other Institutions have contributed to the increasing number of civil servant among other occupation in the study area.

Furthermore, Ogundeji and Fadairo (2018) findings shows that about 38.1% of respondents are single while majority of respondents are 61.9% married, this will further increases existing overpopulation, thus compounding the problem and stressing existing housing and infrastructure that are not initially adequate (Olamiju, 2014). Table 4 also shows 59% of the total respondents earn maximum income of 40,000 naira (110 USD) monthly which fall below official poverty line. The income capacity of individual that lives in the urban centre determines the standard of living and the type of housing facility they occupied. It is a clear statement that vulnerable and flooded prone milieu is mostly occupied by urban poor because of inability to avoid good housing quality (Ogundeji and Fadairo, 2018).

Table 3: Socio-Economic activities of respondents

Occupation	Opp. ACE	CAC Oke-Iye	Unimed Campus	Total	(%)
Civil servant	15	25	12	52	40
Trader	8	10	6	24	16
Student	20	6	18	44	29
Farming	2	3	1	6	4
Poultry	1	2	1	4	3
Unemployed	4	4	12	20	8
Total	50	50	50	150	100

Source: Author's archive

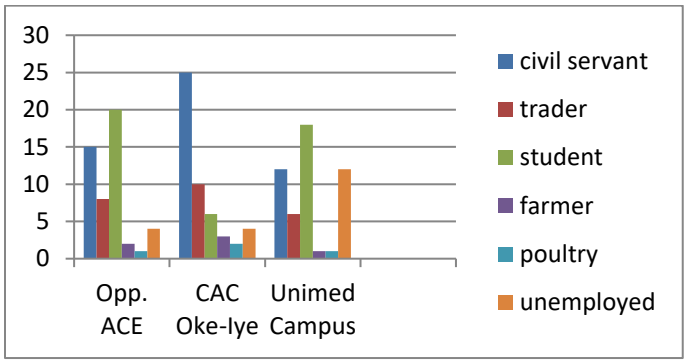

Figure 3: Socio-Economic distribution of respondents
Source: Author's archive

Table 4: Individual income of respondents

Income	Opp. ACE	CAC Oke-Iye	Unimed Campus	Total	(%)
0-40,000	32	20	36	88	59
40,001-80,000	9	14	6	29	19
80,001-120,000	6	7	3	16	11
> 120,000	3	9	5	17	11
Total	50	50	50`	150	100

Source, Author's archive

4.2 Urban activities and urban developmental structures

The feature of impervious material has increase at same rate with urban development. Different type and form of such activities in urban housing include, concrete work, pavement, interlocking, roofs, shed and housing which has reduced surfaces for percolation of runoff and surface water which then accumulated and degenerated to floods. Table 5 shows damage significance due to urban housing seasonal floods in the study area. Most of the house occupants that responded are male and this reflect female marginalization from accessing good housing qualities (Bako, 2012). This observation contributes to women's increasing poverty (UNCHS, 1985).

Table 5: Chi-Square table profiling the sex of respondents in the survey area

Variable/House owners	Property destructions		Total	X^2 – value
	Yes	No		
Male	74	19	93	0.351
Female	43	14	57	
Total	117	33	150	

Source: Author's archive

Using chi-square to test statistic occurrence of one variable if it independence on the other or otherwise, let assume;

$H_0 : \pi_{ij} = : \pi_{i\,.} : \pi_j$

$H_1 : \pi_{ij} \neq : \pi_{i\,.} : \pi_j$

Where; H_0 : Disastrous Flood is significant to urban housing

H_1 : Flood disastrous is not significant to urban housing

Where $X^2 = \sum \frac{(\text{observed frequency} - \text{expected frequency})^2}{\text{Expected frequency}} \sim X^2_{(r-1)\,(c-1),\,\alpha/2}$

Degrees of freedom = (c-1) (r-1) = 2(2) = 4

$X^2_{(r-1)\,(c-1),\,\alpha/2} = X^2_{4,\,0.05/2}$

Hence, $X^2 = 0.351 < 9.47$

Decision rule

The decision rule is to accept the null hypothesis if the computed Chi- Square value is

Lesser than tabulated Chi-Square value otherwise reject the alternate hypothesis.

Decision

The Chi Square calculation was 0.351 which is less than the critical value of 9.47; so therefore, the null hypothesis cannot be rejected if calculated value is less than the table value. In other words, there appear to be a significant association between the two variables: flood damages effect is significant to increasing numbers of urban housing.

General physical condition of the respondents

The general condition of the body, especially in terms of presence or absence of illnesses, injuries, or impairments of the respondents is explain in Table 6, the common ailments and disease experience by people. Malaria is the most infectious disease caused by parasite that can be transmitted by the bite of infected mosquitoes, very common in the tropical, characterized by recurring chills and fever. Other diseases associated with flooding include catarrh, cold, diarrhea, skin disease, typhoid, dysentery respectively. Aside the level of poverty, health challenge contributed to poor production of the urban economic value and loss of lives. Table 8 indicates the pair-wise ranking tools showing most prevalent diseases in hierarchical strength. There could be generally high increase in number of cases of cholera, malarial, water-borne related, measles among residents in the study area. Prevalent disease within the study area is significant to urban housing floods. This is clearly shown in the analysis of variance (ANOVA) presented in Table 7.

Table 6: Common diseases within the study area

Diseases	Opp. ACE	CAC Oke- Iye	Unimed Campus	Total
Skin disease	6	8	7	21
Dysentery	5	8	5	18
Diarrhea	10	9	11	30
Catarrh	15	11	13	39
Asthma	2	3	4	9
Cold	12	9	13	34
Tuberculosis	4	7	6	17
Typhoid fever	6	6	7	19
Malaria	17	16	18	51
Total	77	77	84	238

Source, Author's archive

Table 7: Variance ratio to test significance of mean square treatment

Source of variation	DF	SS	MS	F
Treatment on disease	2	3.630	1.815	0.088
Error	24	492.444	20.519	
Total	26	496.074		

Source: Author's archive

Where; DF= Degree of freedom

SS= Sum of square

MS=Mean of Square

F= F-calculated (F-cal)

H_O : The average diseases occurrence (mean) is the same.

H_1 : The average diseases occurrence (mean) is not the same.

However, F-crit is the table value of $F_{v1,\,v2,\,\alpha/2}$

Where; V1 is the freedom of degree treatment = 2

V2 is the degree of freedom error = 24

α is the level of significant = 0.05

F-crit = $F_{v1,\,v2,\,\alpha/2} = F_{2,\,24,\,0.05/2} = F_{2,\,24,\,0.975}$.

Decision rule

Since F-cal <F-crit, decision rule is to accept null hypothesis and to reject alternate hypothesis.

Decision

Thus, F-cal (0.088) is less than that of the table value. Hence, the treatment is equal, therefore the hypotheses is hereby accepted. The disease occurrence is significant to urban housing flood within the study area.

Table 8: Pair-wise ranking of disease

Flood problems	1	2	3	4	5	6	7	8	9	Rank
1 Malaria	X									1st
2 Skin disease	1	X								5th
3 Dysentery	1	5	X							7th
4 Diarrhea	1	5	3	X						3th
5 Catarrh	1	5	7	5	x					2nd
6 Asthma	1	5	7	6	5	x				9th
7 Cold	1	3	7	7	6	4	x			4rd
8 Tuberculosis	1	7	3	8	6	6	6	X		8th
9 Typhoid fever	1	7	3	9	4	2	2	2	X	6th
Frequency	8	5	7	0	1	2	4	3	6	

Source, Author's archive

A study by Ogundeji and Fadairo (2018) shows large cumulative 77% of rooming and flat system are with no good toilets and kitchen when compare to cumulative of duplex, storey building thus, has further compounded the health condition of residents and are generally occupied by low income earners. Generally, people who build on marginal lands with no title document and infrastructure are considered poor (Nubi, 2008). It is therefore appropriate to state that occupants of flood prone area are the poor in the society (Ogundeji and Fadairo, 2018). Observation shows that 58 buildings (43.03%) have encroached within 30m setback to the river banks while number of buildings that encroached into the statutory 60m setback of seasonal river has increased. Also, the modalities of waste disposal shows 9.5% of respondents use dustbin, 19.9% use incinerator, 23.8% dispose their wastes in drainage and river channels, while over 50% use refuse dumps. This greatly contributes to water flows obstruction, flooding and environmental degradation (washing away of soil, destruction of agricultural land; plants, livestock and properties damage; houses, sheds, electricity) and consequently a health catastrophe in Odosida.

Recommendations

It was discovered that poor economic and income value has an influence on housing quality. This problem are to be solved majorly by the government through housing provision, government acquisition of land, provision of better income opportunity, incentive or relive materials to the affected flooded area among others.

The ANOVA Table also shows that there is significant relationship between illness and flooding in the study area with serious adverse effects on environment and the health of city residents. Hence, total relocation of urban housing from vulnerable or prone area especially environment characterized with lowland and other delineated area by government for the purpose of safety of life. It is noted that reduction of flood impact is not enough for life safety. Hence, lifes has worth more than wealth (multiple properties) and demand relocation to high ground.

The Land Use Act of 1978 which entrusted all land into the hand of Governor of states in Nigeria has also, automatically added to their responsibility the diligent to study the landmass in compass, to mark out, delineate or restrict urban dwellers from occupying marginal, vulnerable and prone area within the urban centers.

Urban housing flood education is essential, to increase individual interest and awareness of general information on flooding and mitigation devices. Society should have access to weather forecast, news, lowland or vulnerable restricted environment peradventure through different form of publicity.

Absolute control of floods is impossible but partial control through "flood prevention, flood reduction and flood protection". Therefore, flood protection includes construction of flood walls, dykes (flood embankment), dams and reservoirs to control flood and minimize it effect by regulating its flow or diverting it away from where it could damage properties (Oriola, 2000).

Findings also shows that high proportions of urban dwellers dispose refuse into gutters and other natural water path especially when it is raining. Thus, aggravates flooding. Hence, appropriate mode of wastes disposal by public or government refuse collector should be encouraged.

Free movement of water on channels will reduce flood occurrence during rainy season. The river valley, channels as well as gutters should be properly monitored during rainy seasons to avoid blockages.

Set-back laws must be enforced by planning authorities and related agencies for all structures close to the rivers, valley and lowland in urban areas. A set back to streams for any structure is 30 meters and in a specified cases above 30 meters (Ogunbodede and Sunmola, 2014).

Aside roofs of urban houses, the pavement, interlocking, concrete, asphalt on road and no room for landscape reduces rainfall percolation. This resulted water is added to surface run-off and flood the environment without adequate channel or drainage. Thus, a reduction in concretized surface of urban environment will reduce flood in the urban housing area as more of the surface run off will percolate to join underground water.

Conclusion

Urban housing flood disaster is one of the environmental problems in Nigeria, the impact got aggravated because of people, society and urban housing activities (Ogunbodede and Sunmola, 2014). The havoc in returns did not only include economic loss but also "health challenges and consequentially loss of life". It is therefore a need for man

and urban housing activities to be harmonized in relationship to the environment so as to reduce flood and its effects on life which is more important to properties. It is a clear statement that vulnerable and flooded prone milieu is mostly occupied by urban poor because of inability to access quality housing. There could be generally increasingly cases of cholera, malarial, measles and water-borne diseases among residents in the study area if flood persist thus, among other recommendations, total relocation of urban housing from vulnerable or prone area especially environment characterized with lowland and other delineated area by government for the purpose of safety of life to higher ground. Researchers' mitigations to the impact of flood would be adequate if in addition, total relocation of urban activities from prone, marginal and vulnerable area. Thereafter, there would be guarantee of safety of life and properties. Furthermore studies on comparative evaluation of urban housing vulnerability to flood on highland and lowland, environmental disruption of urban housing and also, urban housing poor telecommunication challenge on lowland will contribute to knowledge through additional investigation. Conclusively, result shows that there is correlation between flood; and marginalization to adequate housing quality, urban housing and disease occurrence within the study area.

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RESEARCH ARTICLE

Toward environmental sustainability: Nexus between tourism, economic growth, energy use and carbon emissions in Singapore

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Abstract
Singapore is a renowned tourist destination; however, the country's rapid economic growth has led to rising energy consumption and carbon emissions. This study aims to examine the factors that contribute to carbon dioxide (CO_2) emissions in Singapore, including tourism, economic growth, and energy use. The dynamic ordinary least squares (DOLS) approach was used to analyze time series data from 1990 to 2020. The results of the empirical study revealed that the tourist coefficient is positive and significant. A 0.50% increase in CO_2 emissions relates to a 1% increase in tourism activities over time, according to the findings. In addition, the result indicates that the economy's long-run growth coefficient is significantly negative. This shows that a 1% economic growth will reduce CO_2 emissions by 0.03% in the long run. Furthermore, a positive and statistically significant correlation for energy consumption suggests that a long-term increase of 1% in energy consumption is associated with an increase of 0.88% in CO_2 emissions. To promote the emergence of sustainable development and a low-carbon economy, this article proposed policy recommendations addressing the reduction of emissions and the promotion of ecologically responsible and sustainable tourism while boosting the utilization of renewable energy technologies.

Keywords: CO_2 emissions; Sustainability; Tourism; Low-carbon economy; Renewable energy

Introduction

Most greenhouse gases (GHGs) in the atmosphere are CO_2, and humans are responsible for most of these emissions. Human activities that contribute to climate change include using fossil fuels for energy and cutting down trees (Raihan et al., 2018; Jaafar et al., 2020; Raihan et al., 2021a; Raihan et al., 2021b; Isfat & Raihan, 2022). CO_2 emissions are expected to have devastating effects on the global climate system and every area of human existence. Due to atmospheric carbon dioxide sensitivity, the global climate system is quite sensitive. This is because climate change is expected to be one of humanity's biggest issues in the next decades (Raihan et al., 2019; Raihan et al., 2022a; Islam et al., 2022). Thus, reducing carbon dioxide emissions and enhancing the environment are two of the most critical global issues that must be tackled immediately to promote sustainable growth and mitigate climate change (Raihan & Said, 2022; Raihan & Tuspekova, 2022a). As a small, lowland city-state with one of the world's most open economies, Singapore is especially vulnerable to climate change's negative effects (Raihan & Tuspekova, 2022b). Singapore has ratified several international conventions to limit its carbon emissions and mitigate climate change. The Kyoto Protocol and Paris Agreement are examples of these conventions. As a result, understanding the main elements that affect CO_2 concentrations is crucial to improving Singapore's environment. Tourism, energy security, economic growth, and environmental sustainability are all crucial in Southeast Asian countries like Singapore. If modern growth methods cannot be separated from natural resources, the ecosystem will degrade (Raihan et al., 2022b).

Sustainable tourism is garnering global attention due to the direct, indirect, and induced economic effects of the tourist industry’s expansion. Singapore, one of Asia's most industrialized nations, relies heavily on tourism (Katirciolu, 2014). Singapore's economy also benefits from tourism. More than three times the country's population visited Singapore in 2019. However, the tourism industry's key players' decisions are affected by its fragility. According to the UNWTO, worldwide travel will peak in 2030. Because of this, global revenue is expected to reach $2 billion every year (Raihan et al., 2022c). Tourism boosts economies

worldwide (Voumik et al., 2022a). However, tourism increases the need for energy to power transportation, accommodation, and support facilities, as well as food production and tourist site management, all of which can harm the environment (Raihan & Tuspekova, 2022c). The UNWTO estimates that tourism accounts for 5% of global emissions. Seventy-five percent of tourism emissions come from transportation, while twenty percent come from accommodations (Raihan & Tuspekova, 2022d). As a result, when economy and transportation activities are included, the country's energy usage illuminates the link between tourism growth and CO_2 emissions (Raihan & Tuspekova, 2022e). Tourism's importance in economic growth, particularly in Singapore, has been ignored in emission models due to the idea that tourism drives economic growth. Singapore has become one of the world's wealthiest nations due to its economy's rapid growth in recent decades. In 2019, Singapore's GDP per capita was USD 61174, ranking third worldwide (World Bank, 2022). However, whether unfettered economic growth harms the environment and generates enough cash to pay for environmental protection affects environmental development and sustainability plans. Environmental development and sustainability plans will be rescinded if unfettered economic growth harms the environment (Raihan et al., 2022d). Conversely, the environment could be improving due to the economy's ongoing replacement of polluting technologies with cleaner ones (Raihan & Tuspekova, 2022f). Because of this, assessing if Singapore's economic growth is linked to environmental sustainability is one of the most important things to undertake. Singapore's amazing economic growth is also linked to an increase in energy consumption and tourism. Due to its various energy resources, fast industrialization, and rising tourism Singapore's economy is one of the world's strongest. Singapore's growing energy needs can only be fulfilled by burning a range of fossil fuels (Mehmood, 2021). Singapore's rising dependence on fossil fuels for energy has increased CO_2 emissions and degraded the environment. Due to rising energy needs, As a result, there is widespread concern about rising emission intensity, especially in the energy sector. Thus, climate change has exacerbated Singapore's energy conservation debate. Because of this, it is more important than ever to understand how tourism, energy consumption, economic growth, and CO_2 emissions are linked.

However, despite the fact that the interplay between CO_2 emissions and their causes has recently been a prominent issue of discussion among researchers worldwide, only a small amount of research has been done in Singapore. To fill this research gap, the present study used econometric approaches to examine the dynamic effects of tourism, economic growth, and energy consumption on Singapore's CO_2 emissions. This study contributes to both the existing literature and Singapore's policymaking process. To be more explicit, the current study fills a research gap in the academic literature by conducting a comprehensive econometric analysis of CO_2 and its determinants in Singapore. The findings may give readers from diverse countries new ideas on environmental dynamics and sustainable management. Time series statistical features and long-term correlations among determinants are shown in this study. The study's findings would provide decision-makers with more complete and relevant statistics to establish successful policies in sustainable and environmentally friendly tourism, a green and low-carbon economy, and renewable energy development. These strategies may lessen climate change and carbon dioxide emissions. This research also aids in analyzing environmental laws and creating new ones. This will help Singapore prepare for global warming's effects. The guidance may also reinforce policies and action plans to mitigate climate change, ensuring long-term sustainable development and environmental quality.

The rest of the article is structured as follows. The Introduction is followed by the section Literature Review, where relevant research studies have been discussed. The third section is the Methodology section, followed by the Results and Discussion section. Subsequently, the last section presents the Conclusion, policy recommendations, limitations of the study, and future research directions.

Literature Review

The association between economic progress, energy usage, and pollution has been thoroughly documented in empirical investigations. A variety of research including numerous countries, factors, and methodologies were considered. Raihan et al. (2022e) revealed the positive effects of economic growth and energy use on CO_2 emissions In Bangladesh utilizing the DOLS, FMOLS, and CCR methods using the data over 1972-2018. Odugbesan and Adebayo (2020) found the positive impacts of economic growth and energy consumption on CO_2 emissions in Nigeria by utilizing the yearly data spanning from 1981 to 2016 employing ARDL, FMOLS, and DOLS techniques. Adebayo and Kalmaz (2021) used ARDL, FMOLS, and DOLS methods to uncover a positive interaction between economic growth and energy use on CO_2 emissions in Egypt by using the data from 1971 to 2014. By employing the ARDL approach, Nondo and Kahsai (2020) revealed the positive effects of economic growth and energy intensity on CO_2 emissions in South Africa from 1970 to 2016. Liu and Bae (2018) revealed the positive effects of economic growth and energy consumption on CO_2 emissions in China from 1970 to 2015 applying the ARDL method. By using time series data over 1985-2013 for 20 African countries, Raheem and Ogebe (2017) found that economic growth and energy use increases CO_2 emissions. By utilizing FMOLS and DOLS estimators using the data from 1971-2014, Vo et al. (2019) revealed that the level of CO_2 emissions is positively associated with economic growth and energy use

in five ASEAN nations (Indonesia, Myanmar, Malaysia, the Philippines, and Thailand).

The influence of tourism on environmental degradation has been a frequent issue of controversy in recent years. Raihan and Tuspekova (2022c) revealed the positive effect of economic growth and tourism on CO_2 emissions in India by applying the DOLS, FMOLS, and CCR methods utilizing the data from 1990 to 2020. By utilizing the ARDL model for Pakistan using time series data from 1981 to 2017, Ali et al. (2020) found that economic growth, energy use, and tourism positively influence CO_2 emissions. Raihan and Tuspekova (2022d) revealed the positive effect of economic growth and tourism on CO_2 emissions in Turkey by applying the DOLS, FMOLS, and CCR methods utilizing the data from 1990 to 2020. By employing the DOLS, FMOLS, and CCR approaches using time series data covering 1990-2019, Raihan et al. (2022c) reported that economic growth and tourism increase CO_2 emissions in Argentina. Ng et al. (2015) found positive impacts of economic growth, energy use, and tourism on CO_2 emissions by employing the ARDL technique for Malaysia using the data over 1981-2011. By employing DOLS, FMOLS, and CCR techniques utilizing the data from 1990 to 2019 for Brazil, Raihan and Tuspekova (2022e) revealed that economic growth, energy use, and tourism have a positive impact on CO_2 emissions.

Furthermore, Ahmad et al. (2019) reported the positive effects of economic growth, energy use, and tourism on CO_2 emissions in Indonesia and the Philippines by applying the FMOLS technique utilizing the data over 1995-2014. Selvanathan et al. (2021) utilized the ARDL methodology to discover a positive effect of economic growth, energy use, and tourism on CO_2 emissions in South Asian countries using data over the period of 1990-2014. By applying DOLS, FMOLS, and CCR estimators using the yearly data spanning between 1990 and 2019, Raihan and Tuspekova (2022g) found that economic growth, energy use, and tourism influence CO_2 emissions positively in Mexico. In addition, Raihan and Tuspekova (2022h) used DOLS, FMOLS, and CCR methods to uncover a positive interaction between economic growth and energy use on CO_2 emissions in Kazakhstan by using the data from 1996 to 2020. By employing the DOLS technique using yearly data between 1995 and 2010, Dogan et al. (2017) reported that economic growth, energy use, and tourism trigger CO_2 emissions in OECD countries. By employing the DOLS, FMOLS, and CCR approaches using time series data covering 1990-2019, Raihan and Tuspekova (2022i) reported that economic growth and energy use increase CO_2 emissions in Nepal. In addition, Zaman et al. (2016) reported that economic growth and tourism positively influence CO_2 emissions in the panel of three diversified World regions including East Asia & Pacific, the European Union, and High-income OECD and Non-OECD countries. However, the review of empirical literature indicates that there is a scarcity of research on the relationship between CO_2 emissions and its determinants in the case of Singapore, although it has become a hot topic among current researchers worldwide. Therefore, the present study attempts to fill up the literature gap by investigating the dynamic impacts of economic growth, energy use, and tourism on CO_2 emissions in Singapore.

Methodology

Data

This study used the DOLS method of cointegration (Stock & Watson, 1993) because it may represent a continuous response variable as a function of one or more predictor components. It can be used to investigate experimental, economic, and environmental data and predict complex system behavior. Singapore is a popular tourist destination, and tourism increases energy demand, CO_2 emissions, and economic growth. Therefore, this study examined tourism, economic expansion, and energy consumption to determine how each of these factors affects CO_2 emissions. Time series data on Singapore from 1990 to 2020 were obtained from the World Development Indicator (WDI) dataset (World Bank, 2022). To assure a normal distribution, the variables are logarithmically converted for estimation. After logarithmically transforming the variables, organizing the features into a bell curve with more conventional proportions improves model fit. This lets us depict data more accurately. Table 1 lists variables, measuring units, logarithmic forms, and data sources. In addition, Figure 1 shows the study variables' annual trends.

Table 1. Logarithmic representations, units, and data sources of the variables

Variables	Description	Logarithmic forms	Units	Sources
C	CO_2 emissions	LC	Kilotons	WDI
T	International tourism	LT	Number of tourist arrivals	WDI
Y	Economic growth	LY	Constant Singapore dollar	WDI
E	Energy use	LE	Kg of oil equivalent per capita	WDI

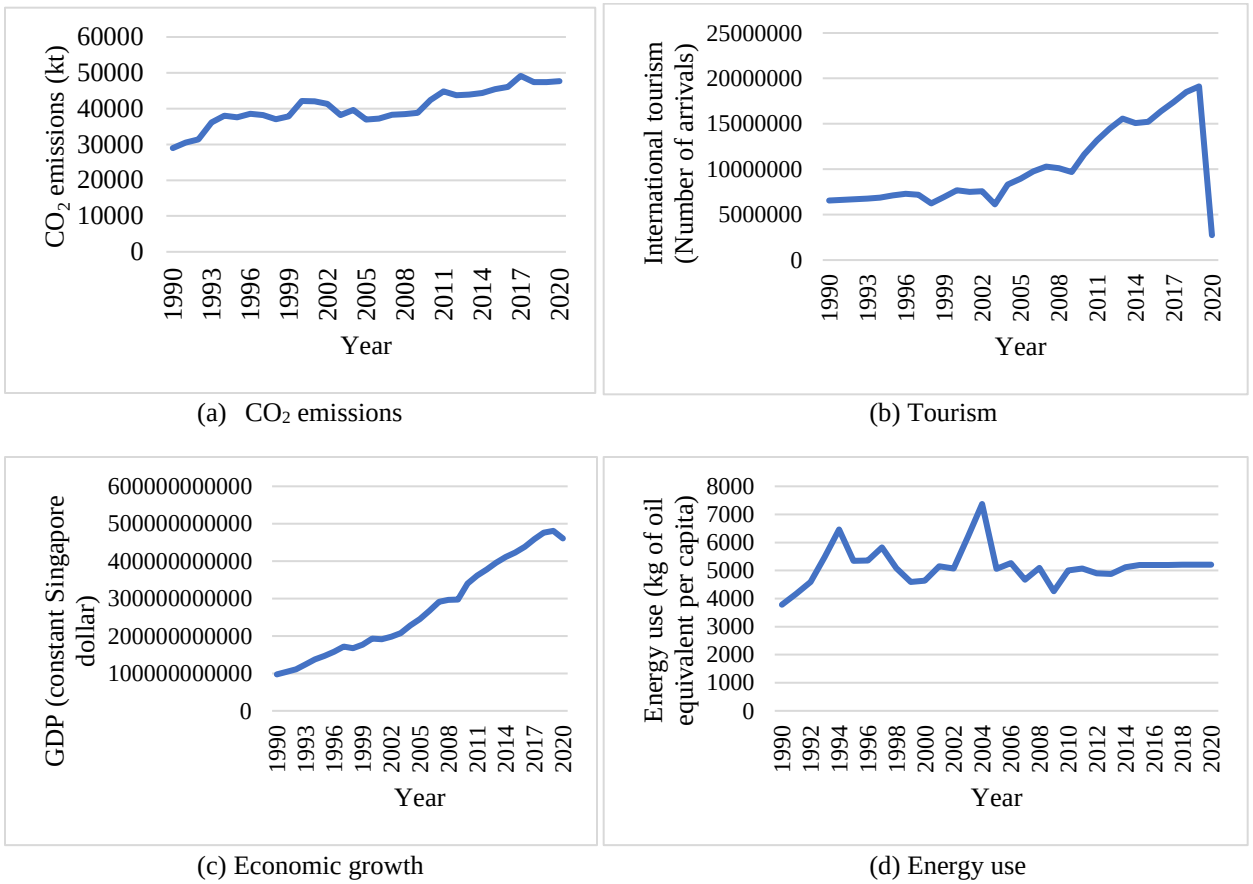

Figure 1. Singapore's yearly trends for the variables studied
Source: World Bank (2022)

Econometric strategies

In theory, tourism contributes to pollution and higher CO_2 emissions, which in turn are linked to rising energy use and a growing economy. This research aimed to estimate the impacts of tourism, economic growth, and energy consumption on CO_2 emissions by plugging relevant data into the following Equation (1) generated within the Marshallian demand function (Friedman, 1949) at time t:

$$C_t = f\ (T_t; Y_t; E_t) \quad (1)$$

Moreover, Equation (2) depicts the empirical model:

$$C_t = \tau_0 + \tau_1 T_t + \tau_2 Y_t + \tau_3 E_t \quad (2)$$

Further, it is possible to use Equation (2) as the econometric model in Equation (3):

$$C_t = \tau_0 + \tau_1 T_t + \tau_2 Y_t + \tau_3 E_t + \varepsilon_t \quad (3)$$

where τ_0 and ε_t stand for intercept and error term, respectively. In addition, τ_1, τ_2, and τ_3 denote the coefficients.
Furthermore, the logarithmic arrangement of Equation (3) can be expressed in Equation (4) as follows:

$$LC_t = \tau_0 + \tau_1 LT_t + \tau_2 LY_t + \tau_3 LE_t + \varepsilon_t \quad (4)$$

Figure 2 depicts a flow diagram of the analytical procedures employed in the study to investigate the nexus between tourism, economic growth, energy consumption, and CO_2 emissions in Singapore.

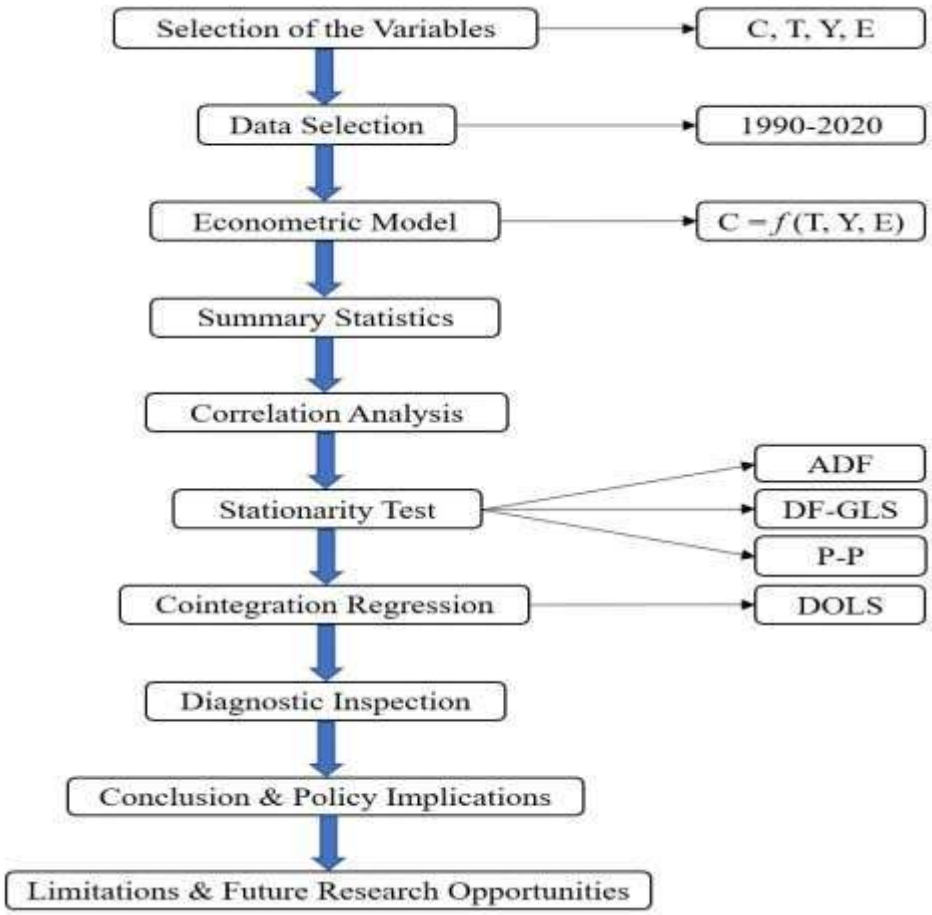

Figure 2. The flow chart of the analysis

Avoiding an incorrect regression requires testing the unit root (Raihan & Voumik, 2022a). First, differentiate the regression variables, then estimate the desired equation using stationary processes. This ensures the experiment's variables won't change (Raihan & Tuspekova, 2022h). In the empirical literature, the sequence of integration must be understood before determining cointegration. When defining the integration order of a series, several unit root tests are needed because their power depends on the sample size (Raihan & Tuspekova, 2022i). The current study used Dickey and Fuller's (1979) Augmented Dickey-Fuller (ADF) analysis, the DF-GLS test proposed by Elliott et al. (1996), and Phillips and Perron's (1998) P-P unit root test. These tests were aimed to find the autoregressive unit root (Raihan & Voumik, 2022b). In this study, the unit root test confirmed that no variable surpassed the order of integration and supported the DOLS methodology as an alternative to cointegration methods.

This study used DOLS to analyze time series data that includes initial difference term leads and lags. It also considers variables that explain outcomes. This is done to preserve endogeneity and compute standard deviations using a serial correlation-free covariance matrix of errors. This ensures data accuracy. The DOLS method ensures that the predicted standard deviations were calculated correctly (Raihan and Tuspekova 2022j). The DOLS approach shows that the incorrect term has been orthogonalized by considering the words before and after each term. This can be achieved by comparing leading and trailing terms. The DOLS test can assess statistical significance as the DOLS estimator's standard deviations follow a normal asymptotic distribution (Raihan and Tuspekova 2022k). The DOLS method incorporates individual variables into the cointegrated framework in mixed-order integration. This can be done by estimating the dependent variable's value with respect to the explanatory components' levels, leads, and lags (Raihan et al., 2022e). The DOLS estimation's main strength is its cointegrated outline, which includes individual integration variables of a mixed order (Raihan et al., 2022f). In the DOLS technique of estimating, one of the I (1) components was regressed with the other variables, some of which were also I(1) variables with leads (p) and lags (-p) of the original difference, while others were I(0) variables with a constant term. This was done to determine which variable best described the relationship between the two sets of variables. Each aspect's value was carefully

evaluated. These features were studied and contrasted before being grouped and summarized. By pooling explanatory component leads and lags, this estimate overcomes small sample bias, endogeneity, and autocorrelation (Begum et al., 2020). After determining that the variables under inquiry cointegrate, Equation (5) was used to estimate the DOLS long-run coefficient.

$$\Delta LC_t = \tau_0 + \tau_1 LC_{t-1} + \tau_2 LT_{t-1} + \tau_3 LY_{t-1} + \tau_4 LE_{t-1} + \sum_{i=1}^{q} \gamma_1 \Delta LC_{t-i} + \sum_{i=1}^{q} \gamma_2 \Delta LT_{t-i} + \sum_{i=1}^{q} \gamma_3 \Delta LY_{t-i} + \sum_{i=1}^{q} \gamma_4 \Delta LE_{t-i} + \varepsilon_t \quad (5)$$

where Δ is the first difference and q is the optimum lag length in the above Equation (5).

Results and Discussion

Skewness, kurtosis, probability, and Jarque-Bera normality tests are shown in Table 2. The kurtosis statistic was used to identify whether the series had light or heavy tails compared to the normal distribution. The empirical evidence shows that each series is platykurtic since every value is smaller than 3, the critical number. Skewness scores around zero suggest that all variables have met the normality premise. Low Jarque-Bera probabilities indicate normal parameters.

Table 2. Summary statistics of the variables

Variables	LC	LT	LY	LE
Mean	10.59614	16.04240	26.21635	8.539070
Median	10.56695	15.93525	26.22507	8.541262
Maximum	10.80243	16.76604	26.89910	8.905262
Minimum	10.27402	14.82420	25.30307	8.238199
Std. Dev.	0.129226	0.432733	0.497200	0.124795
Skewness	-0.584899	-0.224998	-0.201045	0.456229
Kurtosis	2.138226	2.290868	1.825116	2.865745
Jarque-Bera	1.792233	0.370839	1.991788	2.571713
Probability	0.408152	0.830756	0.369393	0.6061676
Sum	328.4804	497.3144	812.7069	264.7112

Table 3 shows the linearity of the variable connection. All parameters appear to be strongly correlated. This shows that when the first variable increases, so do the other variable. This inquiry used unit root tests to assess whether the variables were stationary based on correlation analysis.

Table 3. The results of the correlation analysis

	LC	LT	LY	LE
LC	1.000000	0.829646	0.882937	0.916525
LT	0.829646	1.000000	0.864545	0.927679
LY	0.882937	0.864545	1.000000	0.912535
LE	0.916525	0.927679	0.912535	1.000000

The autoregressive unit root was found using ADF, DF-GLS, and P-P techniques. Table 4 shows ADF, DF-GLS, and P-P unit root test results. Three unit root tests showed that variables were not stationary at the levels but became stationary at the first difference. Thus, the difference-oriented DOLS methodology is suitable for data analysis.

Table 4. The findings of unit root testing

Logarithmic form of the variables		LC	LT	LY	LE
ADF	Log levels	-2.3288	-1.8033	-2.4978	-2.0176
	Log first difference	-4.8421***	-2.7904**	-3.8153***	-5.9125***
DF-GLS	Log levels	-0.7277	-1.7846	-0.3732	-2.1862
	Log first difference	-4.7079***	-2.6944*	-3.9132***	-6.0523***
P-P	Log levels	-2.3158	-1.8033	-2.4979	-2.3458
	Log first difference	-4.8182***	-2.8369**	-3.7357***	-5.7726***

***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Table 5 shows DOLS estimates. The long-run coefficient of LT, which is positive and statistically significant at the 1% level, shows that a 1% increase in tourism leads to a 0.50% increase in CO_2 emissions over time. This study found a strong correlation between Singapore's carbon dioxide emissions and tourist numbers. Tourism increases Singapore's air pollution, which worsens the environment. The study found that more visitors visiting Singapore increases energy usage and climate change. Since the research study's conclusions match those of other Singaporean studies, this discovery is not surprising. Zhang and Liu (2019) found that Singapore's carbon dioxide emissions increased with foreign tourists. In addition, research from other countries, such as Ng et al. (2015), Zaman et al. (2016), Dogan et al. (2017), Ahmad et al. (2019), Ali et al. (2020), Selvanathan et al. (2021), and Raihan et al. (2022c), supports the current study's conclusion that tourism and CO_2 emissions in Singapore are positively correlated. However, if tourism is not planned and controlled, it may harm the environment, which is vital to the tourism industry. Tsai et al. (2014) found that hotels with better service levels emit more CO_2 per guest. International tourism and travel spending increase carbon dioxide emissions in wealthy and developing nations (Zaman et al., 2016). Dogan et al. (2017) also revealed that tourism increases CO_2 emissions through various modes of transportation, touristic infrastructure development, and local government and commercial services. The travel and tourist business is a major contributor to the degrading environment. Tourism generates greenhouse gas emissions in transportation, energy, and heat production (Ng et al., 2015). Tourism harms the biophysical and sociocultural environment. Tourism releases smoke, sulfur dioxide, nitrogen oxides, and other hazardous pollutants into the atmosphere, deteriorating the environment. Tourist activities may damage the ecosystem, making the site less appealing. Waste mismanagement may turn a beautiful spot into the trash. Tourism also causes noise pollution from vehicles. The growth of the airline sector, hotel occupancy, and motorized boat use have all contributed to this issue (Raihan & Tuspekova, 2022b). Sustainable tourism is necessary to reduce tourism's negative impacts on society, the environment, the climate, and the economy.

Table 5. DOLS outcomes: dependent variable LCO2

Variables	Coefficient	Standard Error	t-Statistic	p-value
LT	0.498110***	0.314185	1.585401	0.0013
LY	-0.035536*	0.060398	-0.585401	0.0719
LE	0.880200***	0.329043	2.675034	0.0025
C	3.729782	1.843548	2.023155	0.1153
R^2	0.923172			
Adjusted R^2	0.902524			
Standard error of the estimate	0.057280			
Long run variance	0.007186			
Mean of the dependent variable	10.59614			
F-statistic	1129.36			
Prob (F-statistic)	0.000000			
Root mean square error (RMSE)	0.021297			
Mean Absolute Error (MAE)	0.018543			

***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Singapore is used as a case study to see if economic production and environmental pollution are related. Despite LY's negative long-run coefficient, this discovery is statistically significant at 10%. This means that Singapore's CO_2 emissions will reduce by 0.03% for every 1% increase in economic development. This study found that economic growth did not harm the environment. The result shows that an expanding economy negatively impacts CO_2 emissions over time. The result showed that Singapore's ability to sustainably manage its environment increases with economic development. The study result is supported by Katirciolu (2014), Mehmood (2021), and Mansoor (2021)'s conclusions that Singapore's GDP and CO_2 emissions are inversely related. Studies from other countries also supported our findings. For example, Zaman et al. (2016), Ali et al. (2020), Ng et al. (2015), Ahmad et al. (2019), Selvanathan et al. (2021), Dogan et al. (2017), Raheem and Ogebe (2017), Liu and Bae (2018), Vo et al. (2019), Raihan et al. (2022e), Odugbesan and Adebayo (2020), Adebayo and Kalmaz (2021), Nondo and Kahsai (2020). Singapore's economy will rise which could improve air quality, as predicted by (Mehmood 2021). Even while economic expansion may improve human existence, it is crucial to determine if and how it may be made sustainable (Raihan et al 2022g). Development activities satisfy more societal demands as economic growth rises. These actions increase pollution, waste, and environmental damage (Raihan and

Tuspekova, 2022b). Thus, economic activities appear to protect and improve the environment rather than endanger it. However, not all economic growth is destructive to the environment or incompatible with environmental preservation. As income rises, people will be able to donate more to causes like environmental protection and pollution reduction. Tech-driven economic expansion boosts productivity and reduces pollution.

This research focuses on Singapore's high energy usage and environmental degradation. This study confirmed that fossil fuels constitute Singapore's main energy source, which increases CO_2 emissions over time. The anticipated long-run coefficient of LE is positive and statistically significant at the 1% level, indicating that a 1% increase in energy consumption in Singapore increases CO_2 emissions by 0.8%. As energy consumption rises, the environment will deteriorate. According to DOLS's extrapolations, greater tourism in Singapore boosts the economy but worsens the environment due to higher energy usage. This study's finding is consistent with Singapore's study by Katirciolu (2014). The positive association between energy use and CO_2 emissions supports previous studies that found many nations largely rely on coal, natural gas, and oil, which increases CO_2 emissions and environmental deterioration. For example, Dogan et al. (2017), Raihan et al. (2022a), Raheem and Ogebe (2017), Liu and Bae (2018), Vo et al. (2019), Raihan et al. (2022e), Odugbesan and Adebayo (2020), Adebayo and Kalmaz (2021), Nondo and Kahsai (2020), Ali et al. (2020), Ng et al. (2015), Ahmad et al. (2019), Selvanathan et al. (2021), and Raihan et al. (2022f). The present study's result shows that Singapore's environmental quality is worsening as energy demand rises. Despite this, 86% of Singapore's primary energy comes from petroleum and other liquids, and 13% from natural gas. Thus, building a renewable energy infrastructure that can replace fossil fuels is the most important policy. Renewable energy sources are needed to ensure sustainable development and mitigate climate change's negative effects (Raihan et al 2022h). Renewable energy boosts the economy and lowers carbon emissions. It is eco-friendly and other benefits include increased energy availability and energy security (Voumik et al., 2022b).

As global environmental consciousness rises, Singapore must switch to renewable energy sources to enable the use of environmentally friendly energy sources and the creation of an eco-friendly ecosystem. Renewable energy accounts for less than 1% of Singapore's primary energy demand. Singapore needs a comprehensive renewable energy policy to transition to a low-carbon economy. However, the Singaporean government is investigating several ways to cut carbon emissions. The Singapore Carbon Pricing Act started operationally in 2019. This statute required carbon pricing. The Singapore Energy Market Authority (EMA) recently launched "4 Switches." This effort promotes clean power production. The Energy Management Agency (EMA) will research energy storage technologies for variable energy flows and potential technical solutions including carbon capture and storage. Regional electricity systems are another EMA focus. Singapore approved its "Green Plan" to mitigate climate change. The plan aims to add more than 321 acres of parkland, prohibit new diesel car and taxi registrations starting in 2025, establish 60,000 vehicle charging outlets nationwide by 2030, with two-thirds in public parking spaces and one-third on private property, and increase solar irradiation. Singapore launched a nationwide 111-acre floating solar panel farm in July 2021. The world's most powerful floating solar farm generates 60 megawatts of power. Singapore's five water treatment plants provide enough hydropower. The National Water Agency of Singapore expects the Sembcorp Industries-owned solar farm in Singapore to reduce carbon emissions by 32,000 metric tons.

It's crucial to note that the projected coefficients' signs are constant conceptually and practically. The current investigation uses many diagnostic methods to determine if the predicted model accurately represents reality. This study examines whether the calculated model matches reality. The revised regression model fits the data well, with an R^2 value of 0.92 and an adjusted R^2 of 0.90. These figures show that the independent factors might account for 90% of the dependent variable's change. The F-statistic supports the computed DOLS regression from both the dependent and independent variables. Given the F statistic's 0.0000 p-value, the model's variables' linear relationship is statistically significant. Third, the root mean square error and mean absolute error helped evaluate the model's predictions. The RMSE and MAE figures were near to 0 and did not indicate a negative value supporting the model's fitness. To verify cointegration analysis, this study tested for normality, heteroscedasticity, and serial correlation. Table 6 summarizes the diagnostic test results. Residuals follow a normal distribution, according to four studies. The model also suggests no autocorrelation or heteroscedasticity. To determine model stability, the cumulative sum of recursive residuals (CUSUM) and the cumulative sum of squares of residuals (CUSUMQ) tests were applied. Figure 3 shows CUSUM and CUSUMQ statistics plots after applying a 5% significance threshold to the comparison. This figure shows confidence levels as red lines and residual values as blue lines.

Table 6. The outcomes of diagnostic tests

Diagnostic tests	Coefficient	p-value	Decision
Jarque-Bera test	0.735637	0.5300	Residuals are normally distributed
Breusch-Godfrey LM test	0.725496	0.6102	No serial correlation exits
Breusch-Pagan-Godfrey test	0.562482	0.7169	No heteroscedasticity exists

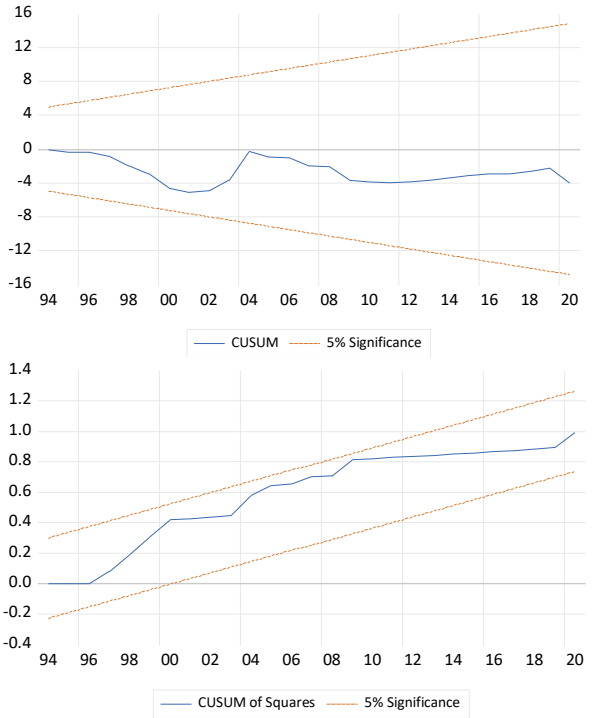

Figure 3. The plots of CUSUM and CUSUMQ

Conclusions and Policy Implications

This study examined the relationship between economic growth, tourism, energy consumption, and CO_2 emissions in Singapore using time series data from 1990 to 2020. The ADF, DF-GLS, and P-P unit root tests were utilized in order to determine the integration order of the series. The findings from the DOLS estimation revealed that tourism and energy use raise CO_2 emissions, which degrade Singapore's environment, but economic expansion decreases CO_2 emissions in the long run. This article proposes environmental policy concepts to ensure the long-term viability of the environment by implementing strict regulatory policy tools to stop environmental deterioration. The outcomes offer recommendations to governments seeking to achieve environmental sustainability while minimizing climate change's effects and adapting to them.

The analysis found that Singapore's government might help markets by creating a rigorous regulatory framework that produces long-term value for emission reduction and continuously supports innovative solutions that reduce carbon dependence. Singapore may continue to establish rules like a high carbon tax, carbon capture and storage, and emission trading schemes to minimize carbon dioxide emissions from fossil fuel combustion in industrial processes and power generation. Decoupling regionally involves changes in centralized nations' policies, conduct, and scientific and technological advancement. This will allow modernization based on technology that can meet growing demand while preserving natural capital. The government's main responsibility is funding research and development to reduce production's resource use and energy efficiency. For Singapore's stronger economic growth to reduce environmental challenges, the economy must convert to renewable energy. Legislators may help corporations create innovative technology and sustainable energy. Institutional alignment also promotes sustainable economic growth and the use of renewable and alternative energy in all economic activities. In addition, environmental regulations must be meticulously followed.

The study suggests using more renewable or clean energy sources to optimize Singapore's energy consumption structure performance. The latest study supported this notion. Conventional energy, which still dominates Singapore's energy use, is the main source of its high carbon dioxide emissions. Singapore may transition to renewable energy to decrease its environmental impact. Due to the limited area for renewable energy generation, practically all of Singapore's energy is imported. Singapore can meet all its renewable energy needs since solar energy is so abundant. Singapore has very strong sun radiation. Singapore may invest in innovation, research, and test beds to improve solar power system efficiency and explore creative ways to integrate them into urban areas. Singapore may examine regional power networks and create low-carbon solutions like low-carbon hydrogen utilization and carbon capture and storage to boost energy security and explore new energy supply possibilities. Singapore is constantly researching new energy sources to promote energy diversity and security. This would be part of nationwide efforts to provide reliable electricity availability. Singapore wants to continue research into nuclear energy and create the necessary capacities to understand nuclear science and technology, even though some technologies, like nuclear power, may become obsolete. Singapore can enhance its energy education programs. Tax incentives, economic subsidies, and government acquisitions can encourage greener energy consumption. There is a possibility that the government will enlist the assistance of the media in order to further its push for "low-carbon behaviors and consumption patterns" and its "green lifestyle notion."

The government of Singapore is able to put in place a system that will hold individuals, tourists, and other interested parties accountable for the damage they cause to the natural environment of the country's most popular tourist destinations. This will allow Singapore to continue to attract tourists to its most beautiful and unique areas. Not only would tourists have an overall more positive experience if all parties involved in the tourism industry were encouraged to embrace sustainability and environmental responsibility in their business practices, but they would also benefit from an increase in their level of education as a result of this. This is due to the fact that visitors would enjoy a more satisfying experience all around. In addition to educational pamphlets and booklets, it is likely that as many public service announcements incorporating easily digestible infographics should be delivered to the general population. People would be encouraged to appreciate the benefits of energy savings and environmental sustainability, as well as to engage in green behaviors while on vacation if these announcements were made, coupled with information on the efforts being made by the authorities and ongoing green development. In addition, the dissemination of this knowledge would motivate individuals to engage in environmentally responsible actions while they are at work. It is of the utmost importance that advancements in transportation technology, such as the employment of high-speed trains and airplanes that consume less fuel, be supported. Because of the rise in tourists, there is now a chance to cut carbon dioxide emissions by updating public transportation, investing in energy efficiency, and enhancing waste management. In order to safeguard the environment, the government might also decide to implement and strictly enforce environmental levies in regions that have a high visitor density and are important tourist destinations. Additionally, the government should make it less difficult for businesses in the tourism industry to adopt environmentally friendly and low-carbon technology in addition to alternative sources of energy for transportation, logistics, hotels, and other activities. This would result in a decrease in the total amount of carbon dioxide emissions and would also prevent excessive consumption of the earth's natural resources. There is a chance that Singapore would tighten the environmental regulations that it already has in place and shine a light on other nations whose tourism industries are contributing to the deterioration of the environment. The concept of "sustainable tourism" can be used to apply to a wide range of distinct sorts of tourism. Some examples of these types of tourism include cultural tourism, ecotourism, tourism that is centered on enjoyment and adventure, and educational tourism. It is vital that the governments in the Southeast Asian region collaborate and coordinate their efforts in order to put proactive measures in place to ensure that tourism is ecologically responsible.

However, despite providing a lot of factual data on Singapore, the analysis contains several shortcomings that need to be addressed in future research. Our study's major flaw was the unavailability of tourism data beyond the study period. This limited the prediction power of the econometric methodologies. Using econometric models or micro-disaggregated data, other nations can conduct more research. The study suggests studying the dynamic effects of socioeconomic and environmental variables on environmental pollution in developing nations with rapid economic growth to balance ecologically sustainable development with emission reduction. This will help to balance environmentally sustainable development and emission reduction. Future research could also consider other development aspects not examined in this study. For example, urbanization, industrialization, trade openness, financial sector development, direct foreign investments, institutional quality, globalization, technical innovation, and others. In order to compare country findings to panel forecasts, a future study may apply more complicated econometric methods. These comparisons with this study's findings may illuminate the relevant literature.

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