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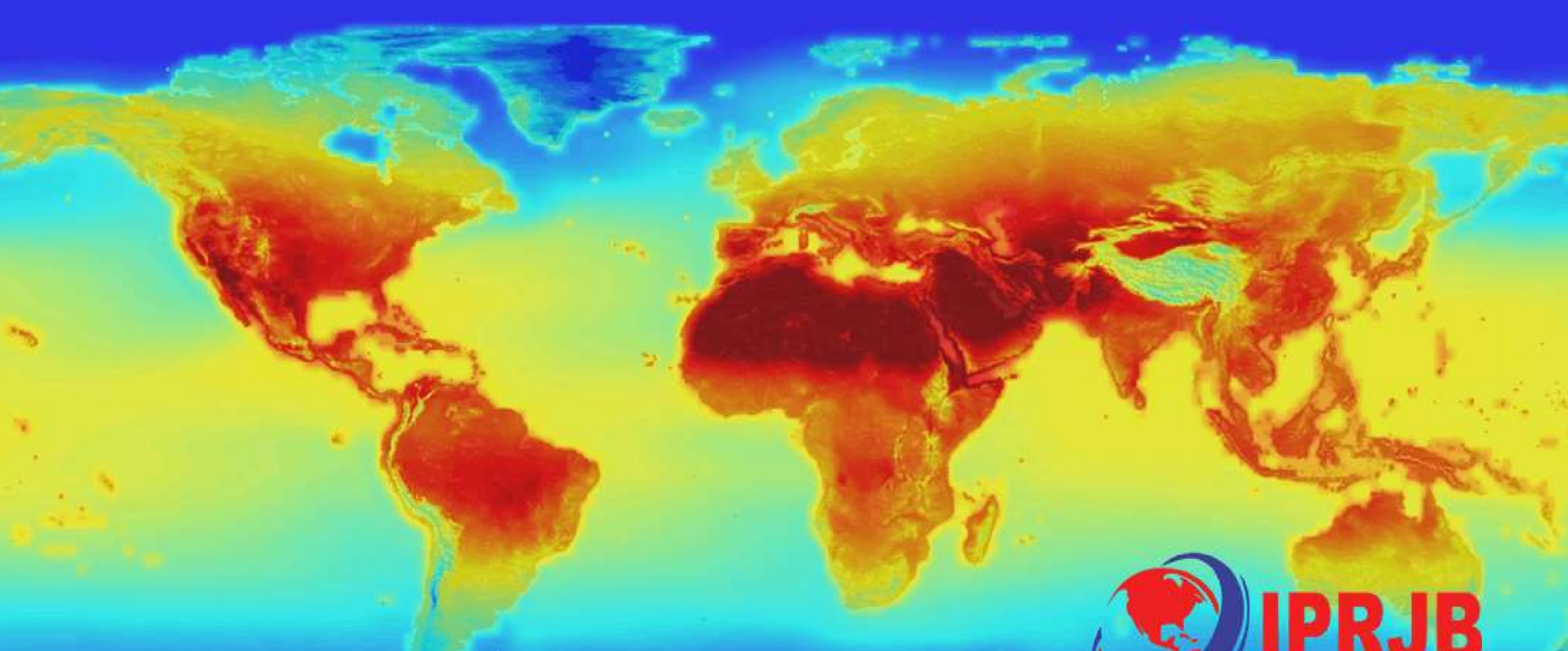

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Abstract

Purpose: The purpose of the study is to examine the impacts of climate change on intermodal transport.

Methodology: This study adopted a desktop methodology. This study used secondary data from which include review of existing literature from already published studies and reports that was easily accessed through online journals and libraries.

Findings: The impact of climate change on intermodal transport is associated with heavy rains, carbon dioxide emissions and greenhouse gases. The study also found that climate change has made the transport sector to develop strategies to mitigate the effect of climate change.

Unique Contribution to Theory, Practice and Policy: The study used the agro-economic models and ricardian model for climate change assessment. The study recommended that additional maintenance and rehabilitation costs may be required to compensate for additional distresses related to climate change. Therefore there is need for heavy investment of emergency funds for repair and maintenance of the way, this includes ports and seas.

Keywords: *Climate Change, Transport, Impacts, Strategies*

INTRODUCTION

Climate Change

According to the IPCC (2013), climate change is defined as a significant change in the average state of climate-relevant variables across time, often over a period of more than 30 years. These variables include temperature, precipitation, and wind. Global climate change represents a significant threat to humanity. The Intergovernmental Panel on Climate Change (IPCC, 2013) asserts that climate change has increased average temperatures of the water and the atmosphere. A rise in the global mean sea level resulted in widespread melting of snow and ice. At the international and local scales many long-term changes in the climate have been noticed on various time ranges. Numerous differences changes include variations in wind patterns, ocean salinity, and components of extreme weather. These changes put social groupings, ecosystems, and community livelihoods in jeopardy (Silva and Leichenko, 2014). The production of food through agriculture and animals is one significant area that will feel the effects of these climate changes.

The Intergovernmental Panel on Climate Change (IPCC) defines climate change as variations in average values or/and changes in features lasting more than 30 years and caused by either a change in the natural environment or human activities (Nkondze, 2014). Almost every sector and area of modern life are impacted by climate change. It affects the timing, volume, and spatial distribution of precipitation, sea level rise, management of tropical storms, and temperatures, as well as the frequency and duration of extreme weather events such extended periods of above-average temperatures, floods, and timing (Nkondze et al. 2014). The consequences of climate change have had an impact on livestock and crop output, as well as how these factors affect how well people can support themselves.

Intermodal Transport

Intermodal transportation can be described as the movement of a person or a load through at least two different modes of transportation, with the transition between them taking place at an intermodal terminal (Mostert, 2017). The idea is very broad, so it can signify a variety of things to various individuals: the transfer of containerized cargo using a mix of trucks, rail, and ocean shipping; special rail services to move lots of containers and trailers over long distances; the main means of transportation for the movement of commodities internationally; an important factor in deciding the transport strategy of the European Community; trips made using a private and public elements combined transportation; and a variety of other things. In order to establish the terminology and create the parameters for this work, one must begin with a few definitions. First, although though intermodal analysis can be applied to both people and freight transportation, this chapter focuses solely on the latter.

Workers in the transportation sector include those who plan, construct, run, and maintain our nation's roads, airports, rail lines, transit systems, and ports (Klopp, 2019). The availability of transportation services is crucial to monetary system and standard of living. In addition to traveling to and from work, people also use transportation for a variety of personal trips. Additionally, transportation networks are increasingly used as mobile warehouses as businesses explore for ways to reduce warehousing costs. As a result, service providers are under more pressure to ensure the prompt delivery of economic goods. As the number of vehicles on the road and the number of miles travelled continue to increase, traffic congestion is becoming a bigger problem.

Relationship between Climate Change and Transport

Because they are sensitive to weather conditions and require extensive planning and financial commitment, transportation systems can be impacted by global warming. Rising sea levels, intensifying storms and frequency, an increase in temperature, modifications to the intensity and frequency of extreme precipitation events, floods, and droughts are some of the current climate conditions that can have an impact on transportation (Christodoulou, 2018). These changes could put infrastructure and transport operations both at danger, with impacts that could be either long-lasting (loss of infrastructure, for instance) or short-lived (disruption of services). Last but not least, climate change may also be beneficial by minimizing delays to transportation at specific regions, such as by lowering ice accumulation. Both slow climatic changes, such sea level rise, and the escalation of catastrophic occurrences have the potential to have an impact on transportation infrastructure. The latter are more disruptive to transportation systems, but their effects are also more challenging to gauge. The complexity of long-term estimates combined with the amount of detail needed to accurately portray the effects on transportation is the main cause.

Extreme weather conditions impact transportation management and infrastructure. Even while infrastructures are built to withstand a variety of pressures throughout the course of their lifespan, the frequency and intensity of extreme weather events will continue to rise, hastening the rate at which they degrade. Transport services must also be controlled to minimize potential hiccups and accidents that may occur more frequently as a result of bad weather (Pregnolato, 2017). The effects of climate change on the transportation industry will differ depending on the mode and region. Impacts will be significant and expensive, according to the results of the climate change model. Due to the effects, there will need to be considerable modifications made to the way that transportation networks are planned, built, operated, and maintained. Extreme events like storm surges, floods, and wind gusts are more likely to affect transportation infrastructure and operations than small fluctuations in temperature or precipitation. Additionally, compared to infrastructure, transport operations are typically more vulnerable to climate change. Sea level rise and storm surges are just two of the threats that climate change poses to airports. High winds are another major issue, particularly during landing and takeoff. The operation of seaports may be hampered by rising sea levels, storm surges, floods, and strong winds. Floods, in which water levels rise above the maximum allowable extreme weather events that affect inland waterways (IWW) include floods, which cause water levels to drop to dangerously low levels and impose limits on navigation services.

Transport modes and one or more concurrent changes in climate conditions, such as hotter summers, severe precipitation events, increased storminess, and sea level rise, may have an impact on system components., depending on global warming scenarios and the geographic position of regions. According to the PESETA II research, more frequent extreme rainfall events and flooding (river and pluvial floods), which are predicted for several regions of Europe, could raise the cost of maintaining the infrastructure for road transportation, according to Christodoulou and Demirel (2018). Furthermore, storm surges pose a risk of permanent or sporadic inundation for 4.1% of

Europe's coastal road infrastructure. The estimated worth of the infrastructure that is at risk is about €18.5 billion when taking into account the costs of degradation and damage.

Extreme weather events are one of the stressors that transportation infrastructures are built to withstand, but transportation services must be managed to minimize potential disruptions and improve safety during these times. (ACRP, 2012) Despite the fact that extreme weather events cause numerous delays and are becoming more frequent, very few airports are currently looking at strategies to alleviate the consequences of climate change. A closure can be very expensive for certain major airports, and the cost of the airport closures caused by the Icelandic volcanic ash cloud in 2010 was estimated to be 0.5 billion euros per day (Nokkala et al., 2012).

Transport assets are typically vulnerable to both incremental climate change and extreme events (heat waves, heavy downpours, high winds, and extreme sea levels and waves), and they are especially vulnerable to extreme events whose occurrence is regarded as relatively unlikely in comparison to typical weather variability and maintenance. A previous review (ECE, 2013) of climate change impacts and adaptation for international transport networks found that: For instance, due to the high coastal sea levels brought on by the hurricane's storm surge, the superstructure of the Gulf Coast bridges in the United States of America was severely harmed by loads from direct wave impacts (USDOT, 2012).

Increases in heat wave frequency and duration pose significant challenges to railway, road, and airport operations and services due to, among other things, the buckling of rail tracks, the implementation of speed restrictions (slower train speeds once a certain heat threshold is reached), damages to road surfaces (such as softening, rutting, flushing, and bleeding), and reductions in aircraft payloads (Palko, 2017). According to predictions, there will be more days that are extremely hot (Kearl et al., 2017). This could result in more road infrastructure failures. The performance and resilience of pavement may be impacted by deterioration and/or subsidence brought on by drier and hotter summers. The International Climate Change Adaptation Framework for Road Infrastructure (developed in 2015) is being improved upon by the World Road Association, PIARC, in order to increase the resilience of road infrastructure at the policy, strategic, system, and project specific levels.

A prolonged operating season and the opening of shipping lanes in Arctic waters are two potential new opportunities that warming temperatures may bring about for global marine transportation networks. However, such warming is linked to navigational risks, such as the summer sea ice's increased mobility, greater coastal erosion brought on by an increase in coastal wave activity, and extreme sea levels at the northern coastlines of Canada, the Russian Federation, and the United States of America (Vousdoukas et al., 2018). All of these point to persistent challenges for coastal infrastructure, exploration, and shipping (Palko, 2017). Reduced sea ice extent (SIE) could make it easier to reach significant hydrocarbon deposits (in the Beaufort and Chukchi Seas), improve community resupply, and boost global trade, opening up new economic prospects for Arctic communities. Changes in climate are causing more freeze-thaw cycles in the northern and southern ECE regions, which could disrupt the infrastructure. For instance, frozen-thawed cycles in Canada may result in the erosion or damage of airport runways, taxiways, and roads (Palko, 2017).

Climate variability will have a disproportionately negative influence on the infrastructure of coastal transportation (coastal roads, trains, seaports, and airports). Along with the aforementioned difficulties, they will also need to adjust to an increase in marine coastal flooding. In the 2030s, marine coastal flooding will pose a considerable risk and necessitate significant technological adaptation measures, according to a new study on climate risks for seaports and coastal airports in the Caribbean (Monioudi et al., 2018). Coastal inundation has the potential to make transportation systems useless for the duration of the event, damage terminals, intermodal facilities, freight villages, storage facilities, and cargo, and so cause supply chains to be disrupted for prolonged periods of time.

Road infrastructure is impacted by climate variability both directly and indirectly, which exposes the roads to more traffic damage (Allen, 2019). Pothole-caused road damage can delay the delivery of goods across the nation, cost money, and cause accidents (Nkomo et al., 2019). Rural roads have important roles in raising revenue in rural areas and alleviating poverty. In addition to being crucial for connectivity, the road network is also crucial for supporting industrial growth and the economy (Luo and Xu, 2018).

The effects of climate change on infrastructure in Africa are increasingly being studied. The majority of the continent's roads are rural ones, and more than 70% of them are estimated to be in fair or declining condition (Koech, 2022). According to climate models, the climate will probably change dramatically in the future. According to Hartmann's (2013) estimate, the world temperature has risen since 1950. This could lead to unpredictable rainfall and other changes in the hydrological cycle.

Due to their low capacity for adaptation and socioeconomic vulnerability, communities in Africa are most negatively impacted by climate-related disasters (Owusu and Nursey-Bray, 2019). In order to improve quality of life, climate resilient road infrastructure is essential in rural areas (Le Roux et al., 2019). Feeder roads, culverts, and bridges are all damaged by climate-related occurrences (Wang et al., 2019). Due to its frequent vulnerability to heavy flooding, Mozambique has been determined to be very vulnerable to change in terms of rural accessibility (Allen, 2019). According to Berg (2019), increased rural accessibility reduces travel expenses and time, encourages resource sustainability, and fosters the expansion of rural companies. According to several studies (Grybait and Stankevien, 2018), there is a connection between the improvement of rural roads for transportation, economic growth, and increased market participation, which helps to reduce poverty.

Statement of the Problem

A variety of intriguing and vitally essential problems about transportation are raised by climate change. For the transportation industry, including the designers, builders, operators, and guardians of the ports, railroads, airports, and other transportation infrastructure in our country (Ambrosio, 2020). Because they are sensitive to weather conditions and require extensive planning and financial commitment, transportation systems can be impacted by climate change. Roads, bridges, railways, ports, and coastal airports are among the harm of way caused by climate change. It also increases the expense of maintaining, repairing, and replacing infrastructure and restricts access to social services. The research by Pregnolato (2017) and Christodoulou (2018) suggest a conceptual chasm since they concentrate on the climatic factors that influence climate change whereas this study focuses more on the effects. Hence, the need for this investigation to close this gap.

Theoretical Framework

This study will be guided by the Agro economic model that was proposed by Van Leeuwen in 2009 and the Ricardian approach model proposed by David Ricardo in 1816.

Agro-Economic Model

The agro-economic model, which employs the crop production function to analyze the economic impact of climate change, generates an issue of underestimating since it does not include the indirect effects of climate change, such as crop conversion and adjusting input parameters for adaptation to climate change. The Ricardian model was created to address this issue, as was indicated in the introduction of this essay (Seo, 2019). The current price of farmland is calculated as the discounted value of future rent, this model to evaluate the economic impacts of weather change. Basically, it argues that, in a long-term balanced condition where all production factors fluctuate along with climatic change, the price of farmland represents the quasi-rent, or the profit from using the farmland. It has the advantage that it can take adaptability into account that cannot be precisely measured or defined. The impact of climate change on the transportation sector will thus be evaluated using this model in light of alterations in the climatic circumstances. It examines how climate change would affect the transportation sector socioeconomically.

The Ricardian Approach Model

Literature does a good job of indicating how vulnerable the agricultural industry is to both climate change and unpredictability. It is reasonable to assume that shifting temperatures and the precipitation they cause will lead to modifications in the water and land regimes, which will have an impact on agricultural output. The production function technique was used in early crop production models to examine how climate change effects agriculture (Bajelj, 2014). These models exaggerate climate change's potential effects on the economy. The approach relied on intricate crop-yield models and, by using only major grains and excluding livestock, considerably fell short of taking into account all agricultural activities that take place in farms. Additionally, farmers were naturally prejudiced against taking adaptation measures when they changed inputs in exchange for others or made adjustments to lessen their vulnerability to climate change. According to Mendelsohn et al. (1994), one way that takes adaptation into account is the riccardian method. Through a comparison of the net profits of farmers in various climates across space, the Ricardian model calculates the effects of the climate. The Ricardian approach implicitly accounts for this phenomenon because farmers everywhere have adapted to their own environmental conditions. In the beginning, developed nations—and specifically American agriculture—applied the Ricardian model to their economies (Huong, 2019).

The approach has additionally been utilized in a larger African context. According to Pourzand (2011), the Ricardian model is one of the nonmarket valuation models that is most often calculated using cross sectional methods and annual data analysis. The results appear to be very steady, despite the fact that numerous years of data should make methods like that more resilient. Repetitive cross sections, according to Kurukulasuriya and Mendelsohn (2017), are insufficient to define the model. Due to the fact that it implicitly considers the adaptation measures taken by the topic under study, the Ricardian model is hailed as the finest model to assess the effects of climate change on the output of crops and cattle.

In a research in Kenya looking at how much agriculture has been impacted by climate change, Kabubo-Mariara and Karanja (2018) used the Ricardian approach. According to the study, climate change has a big impact on Kenyan agriculture. It also demonstrates that, in contrast to a decrease in precipitation, medium and low potential zones have a higher likelihood of being further influenced by the increased temperature caused by global warming. To evaluate how climate change would affect the transportation sector, this model will be employed in the study. According to a study by Berg (2019), increased transportation accessibility encourages resource conservation, economic expansion, and time and money savings during travel.

Empirical Review

Koech (2021) conducted research to ascertain how much climate variability has impacted rural routes used for transporting tea. Surveys and structured interviews were employed in the study. 398 farmers make up the study's sample size. Heavy rains periodically destroy rural tea roads, which has a detrimental influence on tea transportation, the study's findings indicate. To address uncertainties, rural roads should always be maintained. Therefore, based on climate unpredictability and the pattern of heavy rain return periods, there is a need for significant emergency funding investments for the repair and maintenance of rural tea roads.

Mechanistic-Empirical Pavement Design Guide (M-E PDG) to quantify the impacts of projected climatic changes on pavement performance of low volume roads at six sites located in Southern Canada. Oyediji (2021) conducted to assess Impact of flooding and inundation on concrete pavement performance. According to the findings, longitudinal and alligator cracking as well as rutting (in the base and subbase layers of asphalt) will all be made worse by climate change, whereas transverse cracking will become less of an issue. According to present usage of temporal data, pavement designs won't last as long as intended. Additionally, it is anticipated that additional maintenance and restoration expenses may be needed to make up for additional climate change-related hardships.

Hertwich (2019) uses scenario analysis to assess the scope and cost of feasible emission reduction solutions from the urban transport sector in developing countries. The analysis specifically compares the price of greenhouse gas emission reductions from fuel technology options to reductions from actions that support mode shifting. This comparative analysis shows that the most affordable way to reduce greenhouse gas emissions is likely to be a diverse set of actions with a focus on mode shifting.

Nadel (2019) looks into the possibility of significantly reducing greenhouse gas (GHG) emissions from US transportation. They came to the conclusion that no one mitigation strategy alone could achieve the challenging GHG targets, especially given the anticipated rise in global travel demand across all subsectors. Given the variety of vehicle types and requirements in the transportation industry, this places a significant responsibility on vehicle and fuel technologies to decarbonize. This might be accomplished by the deployment of sophisticated vehicle technology and fuels as well as other choices for behavioral change.

Pham (2019) looks at creating a green route model for choosing dry ports in Vietnam. The study used an activity-based emission modeling methodology. This study made clear that when intermodal coastal shipping and truck transportation are employed for export or import container movements in Taiwan rather than truck-only transport, it may result in positive improvements in CO_2 emissions. The main cause of the decline in CO_2 emissions is the efficiency of maritime fuel (heavy oil and diesel) usage in comparison to diesel used by trucks.

Vajjarapu (2020) investigated the consequences of weather changes and flooding on urban transport in the Boston Metropolitan Area. The analysis found that, in comparison to other metropolitan areas in the US and around the world, the Boston Metro Area is already substantially developed, thus there won't be much change in urban infrastructure.

Mills (2007) investigates how drivers can adapt to bad weather. Considering the connection between exposure to rain, particularly heavy rain, snow and slick pavement, the study used a population of 23 Canadian cities. The study's finding that drivers adapt to local weather patterns highlights the need to examine driver adaptations on shorter time frames in order to pinpoint circumstances or driving groups where hazards are especially high. The risk study demonstrates that relative risk is higher in rural locations than in neighboring cities and that collision rates are elevated. According to the data, crash rates rise when posted speed limits rise. These data emphasize the significance of driving speed in weather-related collision occurrence and show that even in bad weather, people still drive faster than the posted speed limit.

Pham (2009) compares truck-only inland transportation's carbon dioxide emissions to multimodal coastal shipping and truck movements. They employ a modeling strategy for emission-based activity. This study showed that switching from truck-only transport to intermodal coastal shipping and trucking for the transportation of containers from and to Taiwan might reduce CO_2 emissions. The main cause of the decline in the effectiveness of marine fuel (heavy oil and diesel) is measured in CO_2 emissions and usage in comparison to trucks burn diesel fuel.

METHODOLOGY

This study adopted a desk methodology. A desk study research design is commonly known as secondary data collection. This is basically collecting data from existing resources preferably because of its low cost advantage as compared to a field research. Our current study looked into already published studies and reports as the data was easily accessed through online journals and libraries.

FINDINGS

The results were analyzed into various research gap categories, that is, contextual and geographical gaps.

Contextual and Conceptual Gaps

Koech (2021) study posted a contextual gap as it examines on one mode of transport and majorly focused on rural roads while this study will focus on all modes of transport. Mills (2007), Vajjarapu (2020);Oyediji (2021);Hertwich (2019); Pham (2009); Nadel (2019), this study presented a geographical gap as this studies were conducted in other countries, the current study is conducted in Kenya. In addition all the other did not mention the impacts of climate change on all forms of intermodal transport.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Based on the results of the literature review, the study came to the conclusion that heavy rains that periodically damage rural roads and the need for vehicles to decarbonize because of emissions of carbon dioxide and greenhouse gases for which the threshold may not be reached are two effects of climate change on intermodal transportation.

The expansion of the transportation infrastructure, particularly in places prone to flooding, has also been influenced by climate change. By raising roadways, the infrastructure is well-built to stop this. Drivers have adjusted by reducing speed as a result of increased rate of collisions.

The study discovered that the transportation industry has developed ways to lessen the impact of climate change.

Recommendations

According to the report, more maintenance and rehabilitation expenses may be needed to cover any additional hardships brought on by climate change. In order to restore and maintain the way, including ports and seas, a significant amount of emergency cash must be invested. Due to the frequency of weather-related collisions, there is a need for regulated driving speed, and as a result, drivers are advised to obey stated speed restrictions. The report suggested using other forms of transportation as well to cut down on carbon dioxide and greenhouse gas emissions.

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