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Assessment on the Operational Management Issues on the Wind Energy Technologies on National Energy Security

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Dissertation submitted to the University of Bristol in partial fulfilment for the Degree of Master of Science in Engineering with Management Intelligent Manufacturing

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ABSTRACT

The occurrence of wind is a consequence of the uneven heating and cooling of different areas throughout the Earth's diverse topography. To attain a state of balance, comparable to the phenomenon of mixing hot and cold water in a bathtub, the Earth's atmospheric air undergoes global circulation, encountering changes in speed as it moves through valleys and accelerates across rivers. This occurrence produces wind, as would be expected. Wind turbines, akin to windmills, use the kinetic energy of the wind via the utilisation of rotor blades that have resemblance to propellers. The blades of these devices may be aligned in either a horizontal axis, like a fan, or a vertical axis, resembling a merry-go-round. Energy security involves several facets, mostly centred on the assurance of long-term availability of energy supplies. This is achieved by timely investments that are aligned with economic improvements and environmental considerations. The importance of wind energy technology has grown in the pursuit of maintaining national energy independence. The research aims to identify and evaluate the Operational Management Issues on the Wind Energy Technologies on National Energy Security. The present dissertation adopts a Positivist research philosophy and applies a quantitative approach to examine the key aspects related to wind energy technologies and their influence on national energy security. Multiple criteria are discovered, and questionnaires are developed to collect data. The survey was conducted using the 'Qualtrics' platform, with a sample size of 96 participants. The collected data was then analysed using Factor Analysis. The primary objective of this research is to provide valuable insights on the effectiveness of wind energy technologies within the framework of national energy security. from the factor analysis the author gathered three components and developed a model for the effective utilization of wind energy technologies for improving the national energy security.

Keywords:- *Wind Energy, National Energy Security, Operational Management Issues, Factors Affecting, Sustainability.*

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DECLARATION

I declare that the work in this dissertation was carried out in accordance with the requirements of the University's Regulations and Code of Practice for Taught Programmes and that it has not been submitted for any other academic award. Except where indicated by specific reference in the text, this work is my own work. Work done in collaboration with, or with the assistance of others, is indicated as such.

I declare that the work is in this dissertation complies with the University of Bristol Ethical procedures and I fulfilled the approved programme's guidance and procedure. This investigation has been approved (ID: 2022-10110-14885) by the Research Ethics Committee at the University of Bristol.

I have identified all material in this dissertation which is not my own work through appropriate referencing and acknowledgement. Where I have quoted or otherwise incorporated material, which is the work of others, I have included the source in the references. Any views expressed in the dissertation, other than referenced material, are those of the author.

I declare the presented dissertation satisfies the requirements of the MSc in Engineering with Management provide insights into the relevant knowledge on business practices issues within the engineering and/or technology sectors. I understand that projects that fails to meet the suitability standard are carry the risk of not meeting some of the programme outcomes.

I am willing for my marked dissertation to be used for training purposes.

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Andrew White
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LIST OF ABBREVIATIONS

IEA	International Energy Agency
OSHA	Occupational Safety ansd Health Administration
FDI	Foreign Direct Investment
SPSS	Statistical Package for Social Sciences

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CHAPTER ONE
INTRODUCTION

A. Background

The phenomenon of wind occurs as a result of differential heating and cooling of various regions on the Earth's rugged terrain. In order to achieve equilibrium, analogous to the process of blending hot and cold water in a bathtub, atmospheric air circulates globally, experiencing variations in velocity as it traverses valleys and accelerates over rivers. This phenomenon generates wind, as one might anticipate (Blaabjerg & Ma, 2017). There exist multiple methodologies for harnessing power from wind energy. Wind turbines have the capability to be constructed in various locations, including land, lakes, and oceans. These locations may range from remote wilderness areas that are distant from the power grid to urban environments, and even expansive plains. The generation of electricity is facilitated by the rotational motion of the turbines (Yaramasu, et al., 2015).

Wind turbines, similar to windmills, harness the kinetic energy of the wind by means of rotor blades resembling propellers. The blades of these devices can be oriented along a horizontal axis, resembling a fan, or a vertical axis, resembling a merry-go-round (Porté-Agel, et al., 2020). The prevailing design typically consists of a vertically elongated tower featuring three substantial blades arranged along a horizontal axis. However, certain vertical-axis wind turbines bear resemblance to eggbeaters, whereas others resemble the traditional windmills commonly found on farms during the past century (Menezes, et al., 2018).

Energy security refers to the continuous and reliable access to energy resources, ensuring their availability remains uninterrupted, while also maintaining affordability (Dźwigoł, et al., 2019). Energy security encompasses various dimensions, with a primary focus on ensuring the availability of energy resources in the long term through timely investments that align with economic advancements and environmental requirements (Ang, et al., 2015). Conversely, short-term energy security pertains to the capacity of the energy system to promptly respond to abrupt fluctuations in the equilibrium between energy supply and demand (Sovacool, 2016).

B. Topicality

Wind energy technologies have become increasingly significant in the context of ensuring domestic energy security (Lucas, et al., 2016). Wind power is considered to be a viable and sustainable energy source that is not reliant on the depletion of finite resources such as fossil fuels. This suggests that countries that allocate resources towards the development of wind energy technologies have the potential to enhance their energy autonomy while diminishing their dependence on imported energy resources (Kardooni, et al., 2018). Moreover, wind energy represents a highly accessible and widely available source of energy that can be harnessed in various regions across the globe. This characteristic renders it an attractive alternative for countries seeking to enhance the diversity of their energy portfolio and reduce their susceptibility to disruptions in supply (Blaabjerg & Ma, 2017). Enhancing a nation's energy security can be achieved by mitigating the risks associated with overreliance on a solitary supplier or geographical location for meeting their energy requirements (Lucas, et al., 2016). The application of the wind energy technologies in the India's National Energy Security is affected by certain Operational management Issues. These issues are caysed by a wide range of factors, and these factors must be tackled for the effective utilization of wind energy technologies in the national energy security in India. The primary objective of this study is to offer a sustainable and economically viable solution for optimising and supplying energy resources to nations through wind farms, by adjusting them according to the national energy security index.

C. Research Problem

The wind power sector in India has encountered challenges in keeping pace with the rapid expansion of the solar sector. Since 2017, the wind power industry has been unable to meet its annual capacity installation target (Blaabjerg & Ma, 2017). Experts and industry professionals attribute this stagnation to several factors, including the transition to the reverse auction route in the wind sector, a dearth of financial incentives, and the complexities associated with securing suitable land in windy areas and establishing power evacuation infrastructure for wind projects. This research aims to address the factors that causes the operational management issues on the wind energy technologies on National Energy Security.

D. Aim of the Research

The research aims to identify and evaluate the Operational Management Issues on the Wind Energy Technologies on National Energy Security.

E. Research Question

- How does the use of wind energy technologies affect the security of the nation's energy supply?
- What are the main Operational Management issues that affect the wind energy technologies to improve national energy security?
- What are the variables that causes the operational management issues of Wind Energy technologies to Improve national energy security?

F. Objectives

- To identify the uses of wind energy technologies on the national energy security.
- To identify the main operational management issues that affect the application of wind energy technologies.
- To identify the factors that affect the operational management of wind energy technologies.
- To develop a model based on the findings of Factor analysis for the optimization of Wind Energy technologies for the strengthening of national energy security.

G. Methodology

This dissertation employs a Positivist research philosophy, utilising a quantitative methodology to investigate the central issues pertaining to wind energy technologies and their impact on national energy security. Various factors are identified, and questionnaires are prepared in order to gather data. The survey was administered through the use of the 'Qualtrics' platform with a sample size of 96 and subsequently subjected to analysis employing Factor Analysis. This study aims to provide significant insights into the efficacy of wind energy technologies in the context of national energy security.

H. Dissertation Structure

➢ *Chapters Overview*

The dissertation comprises several key components, including an introduction that provides background information, a comprehensive critical review of existing studies, a thorough examination of methods and methodology, an analysis and discussion of results, a concluding section, and a proposal for future research. The introduction provides an overview of wind energy and discusses the various factors that influence the utilisation of wind energy technologies. The subsequent chapter elucidates the employed research methodology, subsequently succeeded by the presentation and examination of the obtained results. The model under consideration is delineated in the aforementioned chapters. The conclusion provides a concise overview of the research findings, while the appendix includes a comprehensive list of references and the questionnaire used for data collection.

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CHAPTER TWO
THEORETICAL FRAMEWORK

A. Wind Energy- A Reliable Source of Energy

The terms "wind energy" and "wind power" are synonymous and refer to the utilisation of wind to produce mechanical power or electricity. The mechanical power generated can be harnessed for various specific purposes, such as the grinding of grain or the pumping of water (Olabi, et al., 2021). Alternatively, the mechanical power can be transformed into electrical energy through the utilisation of a generator. Wind is a renewable source of energy that is derived from the sun through a confluence of three simultaneous phenomena as shown in the following figure 1.

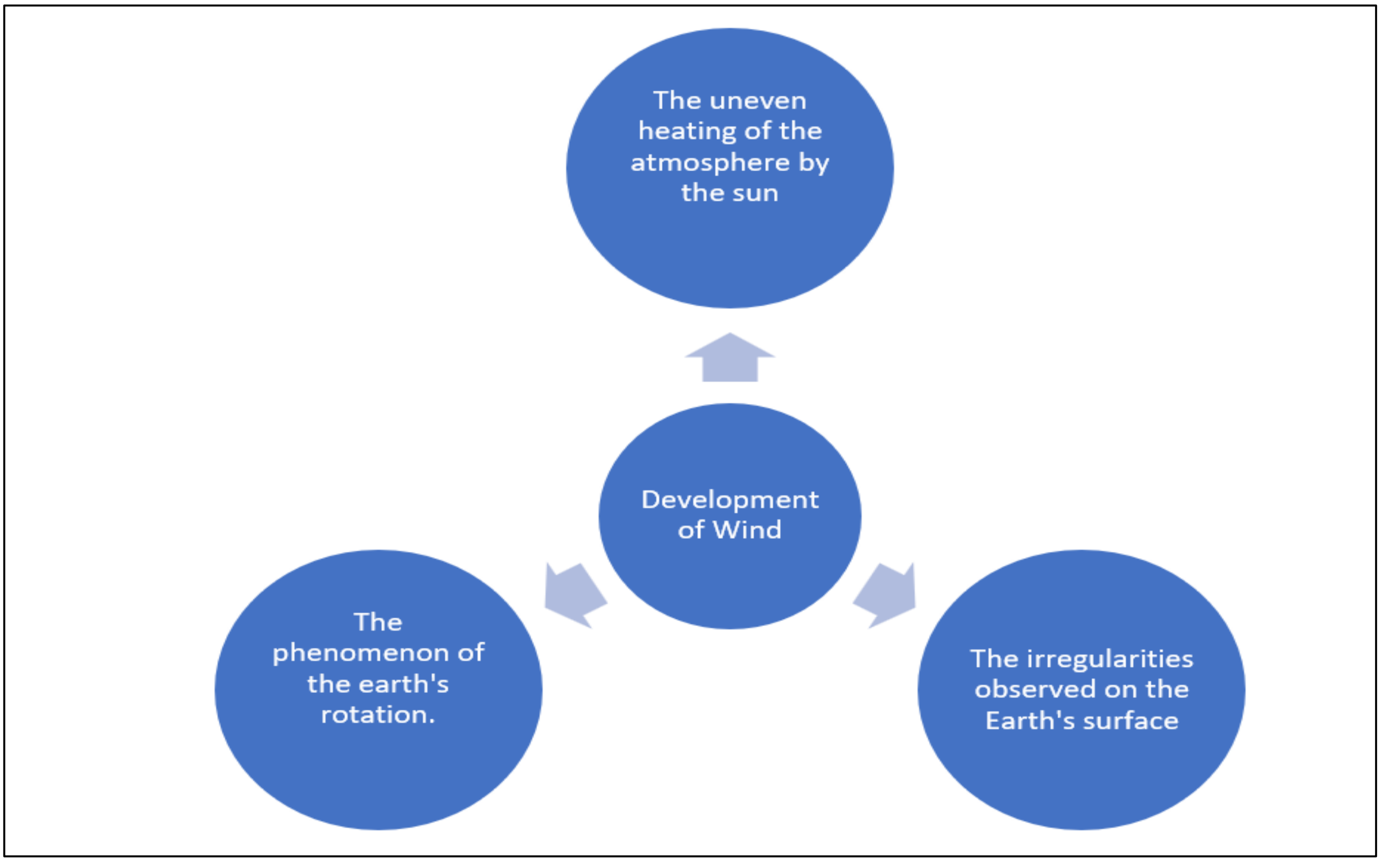

Fig 1: The Phenomena Behind the Development of Winds (Created by Author According to (Leung & Yang, 2012)

The patterns and velocities of wind flow exhibit significant variations across different geographical locations, which are further influenced by factors such as bodies of water, vegetation, and variations in terrain (Chaurasiya, et al., 2019). The utilisation of wind flow, also known as motion energy, by humans is multifaceted, encompassing activities such as sailing, kite flying, and the generation of electricity. The utilisation of wind to generate mechanical power or electricity is referred to as wind power or wind energy. Wind turbines are devices that transform the kinetic energy present in the wind into mechanical power (Kumar, et al., 2016). The mechanical energy can be harnessed for particular purposes, such as the grinding of grains or the pumping of water, or alternatively, it can be transformed into electrical energy through the utilisation of a generator (Wang & Wang, 2015).

B. Wind Energy and National Security

The global electricity systems are undergoing a significant transformation in their generation profile due to the transition towards clean energy. The deployment of variable renewable generation has experienced a significant increase in the previous decade due to the reduction in costs and the presence of supportive policy frameworks. This upward trajectory is expected to persist and potentially intensify in alignment with the objectives related to climate change (Cassuto, 2018). In the present scenario, traditional power plants, particularly those reliant on coal, nuclear, and hydro sources, are experiencing a state of stagnation or decline (Sen, et al., 2016). The implementation of appropriate policies can effectively guarantee consistent energy accessibility throughout the transition period. However, it is important to acknowledge that the dispersed and decentralised characteristics of numerous renewable energy sources do pose a potential vulnerability to cyberattacks. Additionally, several clean energy technologies heavily depend on metals and minerals that are scarce or controlled by a limited number of countries (Majid, 2020).

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According to the International Energy Agency (IEA), energy security can be defined as the continuous and reliable access to energy resources, ensuring their availability without interruption, while also maintaining affordability (Salihaj & Pryimenko, 2017).

Energy security and resilience are closely connected and often intertwined. Countries and jurisdictions vary in their conceptualization of the interplay between energy security and resilience. An instance of this can be observed in the recent initiative by the Government of Laos, wherein they conducted an assessment of vulnerability within the power sector (Cox, et al., 2019). The findings of this assessment were subsequently utilised to inform the development of a comprehensive action plan aimed at enhancing resilience. This plan is perceived as aligning with a wider national objective to enhance energy security. Energy security is commonly regarded as a primary goal, while resilience is perceived as a characteristic of the energy system that can enhance energy security by facilitating the ability to adapt to evolving circumstances and recover from disturbances (Cox, et al., 2019). The following figure 2 outlines the interconnection between energy resilience and National Security.

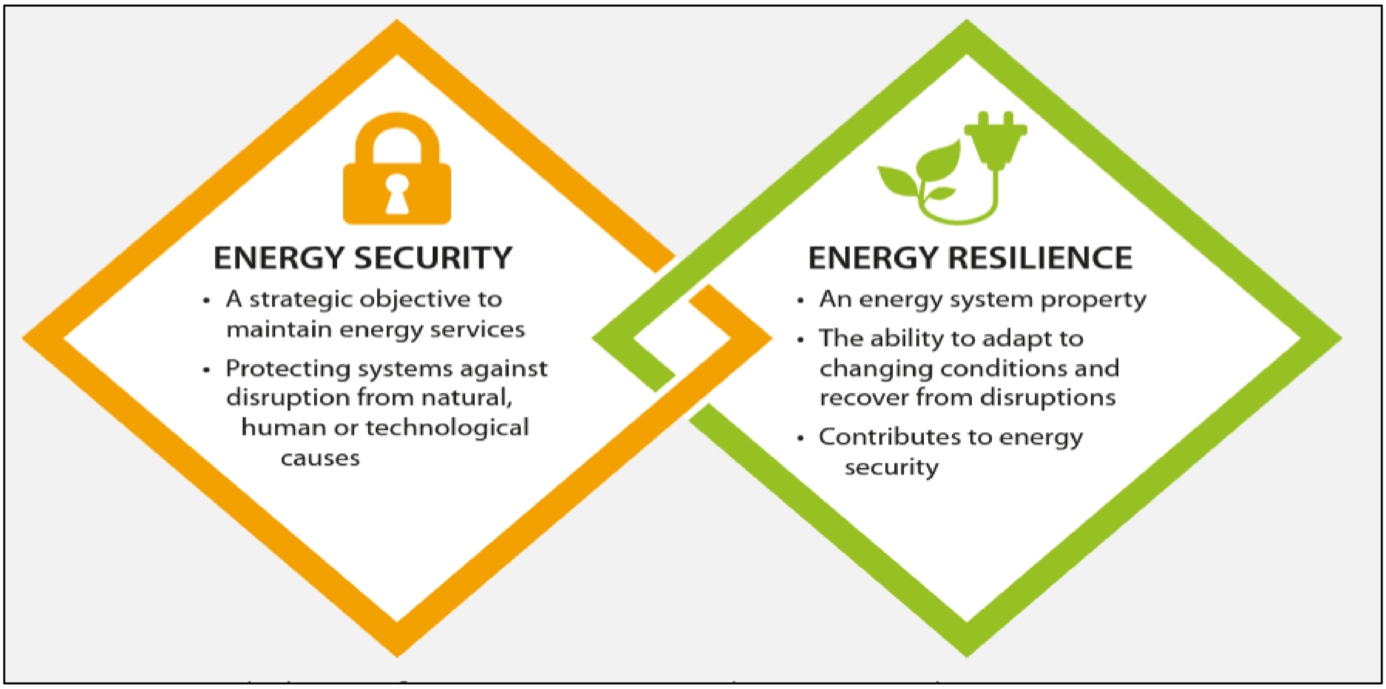

Fig 2: Interconnection Between Energy Security and Energy Resilience (Cox, et al., 2019)

The reliance on energy for economic growth, intensifying weather events, and the increasing potential of large-scale cyberattacks on interconnected energy systems are contributing to the escalating threats faced by energy systems, which have historically been susceptible to disruption. The aforementioned developments underscore the need for a comprehensive comprehension of patterns and susceptibilities in nascent energy technologies, as well as strategic planning and implementation (Cox, et al., 2019).

C. Operational Management Issues in Wind Energy Technologies Application

Wind energy possesses numerous advantages, thereby elucidating its status as one of the most rapidly expanding energy sources globally. In order to enhance the capabilities and societal advantages of wind energy, scholars are actively engaged in addressing technical and socio-economic obstacles, with the aim of promoting a future of electricity that is free from carbon emissions (Pinson, 2013). The operational management issues of wind energy technologies are as follows:

- **Competition with Other Energy Sources-** Nevertheless, it should be noted that wind projects may face challenges in terms of cost competitiveness in regions with insufficient wind resources (Li, et al., 2014). However, advancements in technology, manufacturing processes, and a deeper comprehension of wind plant physics have the potential to further reduce costs. Additionally, the wind industry is expected to face strong competition from natural gas and solar energy sectors, which will likely drive efforts to achieve lower prices and enhance performance (Ahmed, et al., 2020).
- **Carbon Footprint-** The carbon dioxide emissions associated with offshore wind turbines encompass the processes of manufacturing, installation, operation, and eventual decommissioning. In essence, the manufacturing processes of steel and other components, along with vessel transportation and heavy hauling, necessitate the combustion of fossil fuels (Kaldellis & Apostolou, 2017). Efforts are currently being made to develop carbon-neutral alternatives for future applications. However, it is presently inevitable to employ these processes in the construction of offshore wind projects (Wang, et al., 2022). Although wind power is considered a relatively environmentally friendly method of electricity generation, it is important to acknowledge that there are still notable carbon emissions associated with the manufacturing, installation, operation, and maintenance of both

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onshore and offshore wind farms. This encompasses various stages of the production process, such as extraction of raw materials through mining, manufacturing of materials like concrete and steel, transportation, and ongoing maintenance (Gao, et al., 2021).

- **Safety Concerns-** As offshore wind projects expand beyond nearshore sites, the necessity of transporting crew to and from offshore wind installations for installation or maintenance work incurs increased costs and risks. This is due to the depletion of available sites closer to shore (Karasmanaki, 2022). The presence of adverse weather conditions and uncertainties associated with emerging technologies contribute to the inherent risks involved. Wind turbines are utilised for the purpose of harnessing wind energy to generate electricity, and their production and installation are currently being undertaken on a widespread scale throughout the country (Slaven & Dennis, 2012). Employers in the wind energy sector are required to ensure the safety and well-being of their workers by implementing measures to mitigate workplace hazards. It is imperative for workers to actively participate in promoting workplace safety and health, as well as possess the necessary knowledge and skills to safeguard themselves from potential hazards (Kelsey, 1994). Although the industry is experiencing growth, the hazards it presents are not unprecedented, and the Occupational Safety and Health Administration (OSHA) has implemented numerous standards to address them. This webpage offers comprehensive insights into the potential hazards encountered by workers in the wind energy sector (Hammond, et al., 2021). Wind turbines have demonstrated a commendable track record in terms of safety; nevertheless, similar to any form of machinery, turbines are susceptible to potential failures. Safety concerns related to wind turbine operation include blade icing, ice shedding, and potential blade throw (Abdullah, et al., 2023). The following figure 3 outlines the key operational management issues.

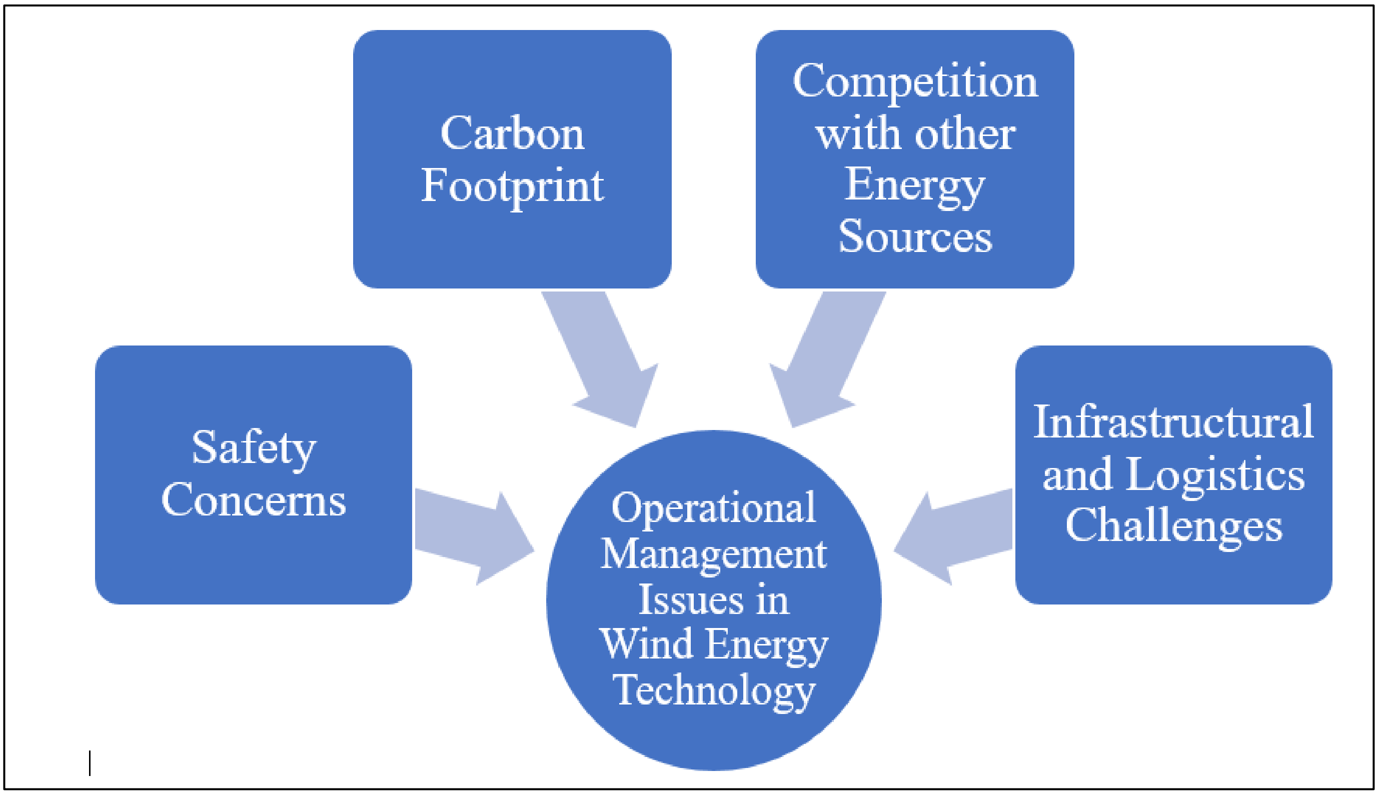

Fig 3: Operational Management Issues of Wind Energy Technologies (Created by Author)

- **Infrastructural and Logistical Challenges-** The infrastructure that facilitates the expansion of the wind industry encompasses all aspects of the manufacturing and installation processes of turbines (Gabriel, 2016). The process encompasses several key stages, namely: identifying a suitable location for turbine placement, choosing an optimal turbine design, procuring all necessary materials for production and fabrication, manufacturing individual components, transporting sizable components to designated installation sites, assembling turbine components, establishing a connection between the turbine and the relevant electrical grid, and ensuring ongoing maintenance of each component over the lifespan of the turbine (Office of Energy Efficiency and Renewable Energy, 2023). The implementation of streamlining measures in this process will result in increased accessibility of cost-effective wind energy for consumers nationwide. One of the foremost obstacles encountered by the wind industry pertains to the considerable magnitude and proportions of wind turbine components (Arshad & O'Kelly, 2019). Given that these components necessitate specialised logistical handling during transportation, it is most advantageous to carry out manufacturing activities in close proximity to the intended installation site. In addition to the towering height of wind turbine support structures, the width of the turbine tower itself constitutes a noteworthy aspect (Gabriel, et al., 2016).

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D. Factors Influencing the Operational Management Issues for Adoption and Application of Wind Energy Technologies

The global imperative for the adoption of sustainable energy technology has arisen as a result of environmental degradation, necessitating the focused attention of researchers and regulators (Wall, et al., 2021). The following factors seems to affect the adoption and application of wind energy technologies.

- *Political Factors*

Sustainable economic growth necessitates the simultaneous management of the increasingly pressing issues of environmental degradation and climate change (Fowler & Breen, 2013). In addition to the detrimental consequences on the natural environment, including the depletion of natural resources and the occurrence of frequent and severe droughts and extreme weather events, the failure to address these challenges will exacerbate disparities in health and social well-being, ultimately leading to a significant increase in the number of individuals living in extreme poverty. Additionally, this will erode the ability of nations to withstand and recover from future disruptions (Sequeira & Santos, 2018).

- *Governance Policies*

The responsibility of establishing governance policies and strategies pertaining to all matters occurring within a country or state lies within the purview of the government. The government possesses the capacity to formulate effective energy conservation policies, establish regulations pertaining to energy production and consumption, and implement appropriate strategies to ensure compliance with these policies and regulations (Stadelmann & Castro, 2014). Through the implementation of a well-structured plan and a strategic approach, governmental entities can effectively assess the various risks associated with energy depletion across different levels. This enables them to develop potential solutions aimed at preserving and protecting energy resources (Schaffer & Bernauer, 15-27). These policies encompass various measures such as the establishment of benchmarks for efficient energy generation and consumption, financial allocations towards the energy industry, and legislation pertaining to technological advancements and innovation, among other aspects.

The government consistently endeavours to develop novel energy conservation strategies and enhance existing solutions with regularity. It is imperative for governmental institutions, either independently or in partnership with other entities, to prioritise the provision of appropriate technologies and alternative energy sources in order to mitigate the depletion of energy resources. The promotion of green energy sources, including wind, biomass, water, nuclear, and solar power, is frequently employed to achieve this objective (Fowler & Breen, 2013). The government has implemented technological systems that enable individuals to monitor their energy consumption and access information regarding more cost-effective energy tariffs and providers (Kardooni, et al., 2018).

- *Bureaucratic and Administrative Hurdles*

There are numerous challenges that emerge during the implementation of renewable energy initiatives, encompassing various administrative obstacles such as planning delays and restrictions, among others (Silva, 2022). The project's development phase experiences unnecessary delays due to a lack of coordination among various authorities and prolonged lead times in obtaining authorization. The acquisition of permission is also accompanied by increased costs as a result of lobbying efforts. Numerous factors contribute to the elongation of the project initiation phase and diminish the level of motivation necessary for investment in renewable energy (Moorthy, et al., 2019).

In order to gain insights into the factors contributing to the effectiveness of public administrations, the Bureaucracy Lab regularly administers surveys to solicit data from the individuals comprising these bureaucratic entities (Nasirov, et al., 2015). The effectiveness of climate change policy hinges upon the awareness and motivation of the individuals tasked with its implementation, as they must be cognizant of the escalating challenges and driven to address them (Burke, et al., 2019).

The phenomenon of bureaucracy arises from the collective agreement of the general population to delegate decision-making authority to a chosen few, often individuals who are not elected. This arrangement has given rise to concerns regarding the potential risks and inefficiencies that it poses to the welfare of citizens, the functioning of government, and the preservation of the environment (Ikejemba, et al., 2017).

- *Economic Factors*

- *Economic Growth*

Based on empirical evidence, there is a discernible relationship between income growth and its impact on both renewable and non-renewable energy consumption, with both positive and negative effects being observed. The impact of domestic investment on the utilisation of both renewable and non-renewable energy sources is positive (Rafiq, et al., 2014). There is empirical evidence indicating a positive relationship between foreign direct investment and the adoption of renewable energy sources (Irfan, et al., 2021). While urbanisation does have adverse effects on the consumption of renewable energy, it does have a positive influence on the consumption of non-renewable energy. The impact of physical infrastructure on the utilisation of both renewable and non-renewable energy sources can be characterised by both positive and negative effects (Mustafa, et al., 2023).

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The enhancement of economic growth has a positive impact on the well-being of individuals, leading to an increase in the proportion of energy consumption by the population. The augmentation of economic growth is accompanied by a twofold increase in energy production, thereby contributing to the sustainability of economic growth. (Burke, et al., 2019)The significance of economic growth is underscored by the primary role played by energy efficiency. The relationship between economic growth and sustainable energy consumption was examined using statistical and econometric techniques (Kumar, et al., 2016).

- *Foreign Direct Investment (FDI)*

Foreign direct investment (FDI) has been widely regarded as a highly appealing aspect across all energy sectors on a global scale. Furthermore, the surge in the energy sector has been identified as the most appealing area for foreign investment, leading to an expansion in both energy production and consumption (Kathuria, et al., 2015). The continuous development of foreign direct investment (FDI) has resulted in a significant increase in energy consumption and energy growth. The connection between the relationship has been extensively explored through the application of diverse statistical and econometric methodologies. The study unveiled the potential and beneficial effects of foreign direct investment (FDI) on the promotion of sustainable energy consumption (Keeley & Ikeda, 2017) (Panse & Kathuria, 2016).

The presence of foreign direct investment (FDI) has been found to have various policy implications that contribute to the enhancement of production, economic development, and energy efficiency (Ang, et al., 2015). The impacts have been determined through the utilisation of econometric and statistical methodologies in order to attract investment. Funds allocated globally play a crucial role in advancing various sectors, particularly energy, with significant implications for overall improvement (Chaurasiya, et al., 2019). Foreign direct investment (FDI) has played a significant role in promoting the sustainability of energy consumption in developing countries, primarily through the implementation of various incentive schemes (Fowler & Breen, 2013).

- *Inflation*

Inflation is widely recognised as a primary economic factor that poses a significant risk to major sectors such as energy and finance. Nevertheless, the escalation in energy prices also serves as a catalyst for foreign nations to redirect their purchasing intentions (Burke, et al., 2019). The macroeconomic factors consistently have a positive impact on the various components of the energy sector. The elements associated with inflation are analysed in a manner akin to the components of economics through the utilisation of diverse statistical methodologies (Majid, 2020). The findings revealed a statistically significant increase in inflation, which supports the notion of a growing influence on sustainable energy consumption within the realm of energy dynamics. Inadequate energy consumption has the potential to impede economic growth, while inflationary factors are also encompassed within economic indicators (Kardooni, et al., 2018). The insignificance of the relationship between inflation and sustainable energy consumption is effectively elucidated through the application of the threshold regression model. The findings elucidated the favourable effects of inflation on energy, thereby fostering the adoption of sustainable energy consumption practises (Menezes, et al., 2018). The primary concern regarding sustainable energy consumption is the potential disruption caused by infinite demand and energy supply, which can lead to inflation. On the other hand, the impact of energy inflation on energy prices enhances the viability of sustainable initiatives in energy consumption (Keeley & Ikeda, 2017).

- *Mechanical Factors*

There are three primary factors that exert an influence on power output, namely wind speed, air density, and blade radius. The optimal siting of wind turbines necessitates consistent exposure to high wind speeds, prioritising sustained wind patterns over sporadic instances of intense gusts (Bastankhah & Porté-Agel, 2017).

- *Wind Speed*

The quantity of electricity produced by a turbine is primarily influenced by the velocity of the wind. Increased wind velocities result in greater power generation as they facilitate higher rotational speeds of the blades. An increase in rotational speed corresponds to a greater amount of mechanical power and subsequently results in an increased generation of electrical power by the generator (Blaabjerg & Ma, 2017). Turbines are engineered to function within a designated range of wind velocities. The boundaries of the range are commonly referred to as the cut-in speed and cut-out speed. The cut-in speed refers to the minimum wind speed required for a wind turbine to initiate power generation. The power output of a wind turbine exhibits a cubic relationship with wind speed within the range spanning from the cut-in speed to the rated speed, where the maximum output is achieved. For instance, in the event that the velocity of wind was to double, the resulting power output would exhibit an eightfold increase. The significance of wind speed for wind power is attributed to its cubic relationship. The cubic relationship ceases to have an effect beyond the designated wind speed (Energy Education, 2023). The following figure 4 outlines the wind power curve.

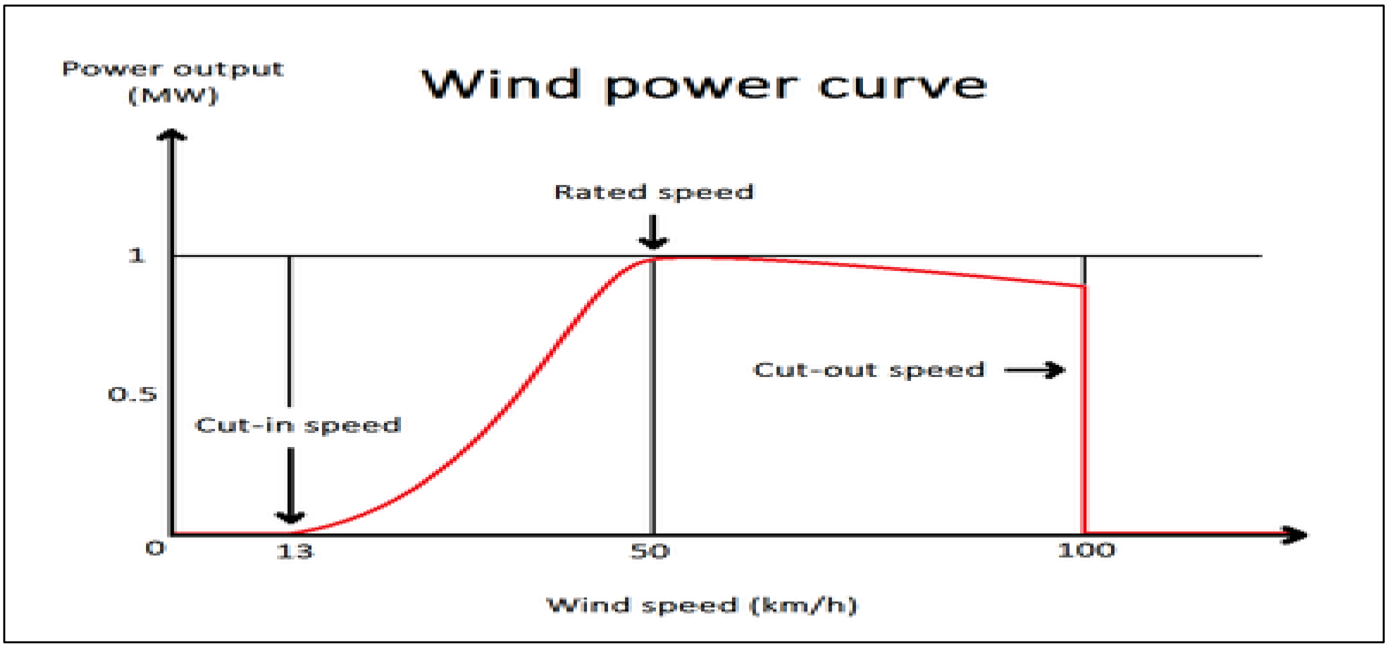

Fig 4: Wind Power Curve (Energy Education, 2023)

Numerous regions across the globe exhibit high wind velocities; however, optimal sites for harnessing wind energy often reside in geographically isolated areas. The utilisation of offshore wind power presents significant opportunities for energy generation (Leung & Yang, 2012).

- *Air Density*

The relationship between the kinetic energy of a moving object and its mass (or weight) is one of proportionality. The kinetic energy present in the wind is contingent upon the density of the air, which refers to the mass of air per unit volume. Put differently, when the air density increases, there is a corresponding increase in the amount of energy that is captured by the turbine (Salihaj & Pryimenko, 2017). Under typical atmospheric conditions and at a temperature of 15°C, the mass of air per unit volume is approximately 1.225 kilogrammes per cubic metre. However, it is important to note that the density of air experiences a slight reduction as humidity levels increase. Furthermore, it should be noted that the density of air tends to increase in colder temperatures compared to warmer temperatures. In mountainous regions, the elevation is significantly higher, resulting in a decrease in air pressure and a reduction in air density (Moorthy, et al., 2019).

The presence of weight in air is attributable to its gravitational attraction towards the Earth's surface. The downward force exerted by the mass of air on the earth's surface results in the generation of atmospheric pressure. Pressure is defined as the physical force applied per unit area, and variations in pressure within a specific region can significantly influence meteorological conditions (Silva, 2022). The concept of atmospheric pressure refers to the exertion of force by an air mass upon the surface of the Earth. It is important to note that the presence of distinct air masses with varying densities gives rise to the generation of wind currents. The movement of wind currents is primarily influenced by the density of atmospheric pressure, whereby denser air generates higher pressure compared to less dense air (Wall, et al., 2021).

- *Blade Radius*

Wind turbines are engineered with the objective of optimising the radius of the rotor blades in order to maximise the amount of power generated. The utilisation of larger blades in a turbine enables the system to enhance its capacity to harness the kinetic energy of the wind by facilitating the movement of a greater volume of air through the rotors. Nevertheless, the utilisation of larger blades necessitates a greater amount of space and higher wind velocities for optimal functioning (Nasirov, et al., 2015). Typically, turbines are positioned at a distance equal to four times the diameter of the rotor. The establishment of a specific distance between turbines is imperative in order to mitigate interference, thereby minimising the adverse impact on power output (Chaurasiya, et al., 2019).

Contemporary wind turbines of considerable size are designed with a hub height, denoting the central point of the turbine, that exceeds 80 metres. This elevation is necessary to access the swifter wind currents located at greater altitudes above the Earth's surface. Turbines possessing a radius of 30 metres have the capacity to produce a maximum of 1.5 MW (mega Watts) of electrical power, whereas turbines equipped with blades measuring 40 metres in radius can generate up to 2.5 MW (Bastankhah & Porté-Agel, 2017).

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The process by which a wind turbine converts wind energy into electrical energy is facilitated through the utilisation of the aerodynamic force generated by the rotor blades, which function in a manner akin to the wings of an aeroplane or the rotor blades of a helicopter. When wind passes over the blade, it results in a reduction of air pressure on one side of the blade (Olabi, et al., 2021). The disparity in air pressure between the two surfaces of the blade engenders both lift and drag. The lift force exerted on the rotor is greater in magnitude compared to the drag force, resulting in the rotation of the rotor. The rotor is connected to the generator, either via a direct drive mechanism in the case of a direct drive turbine, or through a shaft and a series of gears known as a gearbox. This gearbox serves to accelerate the rotation speed and enables the use of a more compact generator. The conversion of aerodynamic force into rotational motion of a generator results in the generation of electrical energy (Pourrajabian, et al., 2021).

➢ *Psycho-Social Factors*

- *Public Acceptance*

Wind energy, as an environmentally friendly and sustainable energy source, is commonly associated with significant and consistent levels of public approval, particularly in light of growing global apprehensions regarding climate change and energy availability (Shepherd & Billington, 2011). The latest empirical data regarding public sentiment towards wind energy, both at the European Union (EU) level and within individual countries, strongly corroborates the positive perception of this particular energy source among European citizens. However, empirical evidence from the implementation of wind projects indicates that social acceptance plays a pivotal role in the effective advancement of individual wind energy initiatives (Walker, et al., 2015).

As a result, the societal embrace of wind power encompasses not only a prevailing favourable disposition towards wind energy technology, but also the growing necessity to make numerous discernible decisions regarding its placement at the community level (Marrero, et al., 2021). Significantly, it is at the local level where the technical aspects of wind energy intersect with the daily lives of individuals, as well as the social and institutional contexts of the communities that accommodate these developments. The correlation between the overall favourable perceptions of wind power and the local approval of wind energy initiatives is not inherently evident (Yates, 2019).

- *Citizen Engagement*

The concept of "citizen engagement" has gained significant attention in public policy discussions in democratic countries. It is recognised that engaging with citizens and incorporating their perspectives in policymaking and decision-making processes is crucial for effective governance (Fast, et al., 2016). As a result, the examination of how technologies are socially accepted now places greater emphasis on the "institutional arrangements," specifically the interactions between the technology, its advocates, and the community. This is particularly relevant in recent studies investigating the factors that contribute to the success or failure of wind farm projects, with a focus on the relationship between local opposition and the levels of community engagement, fairness, and compensation (Walker, et al., 2015).

- *Stakeholder Acceptance*

Stakeholder engagement plays a crucial role in project proposal, scoping, and siting, facilitating the harmonisation of the wind energy and marine renewable energy sectors with the interests and expertise of local communities in order to attain the most favourable result (Enevoldsen & Sovacool, 2016). It is imperative to identify and engage stakeholders at an early stage and maintain ongoing consultation throughout the duration of the project. Developers ought to be mandated and/or directed, via industry representative frameworks, to implement comprehensive and adaptable approaches for community engagement in order to foster continuous dialogue (Spiess, et al., 2015). The following figure 5 outlines the factors identified from literature review.

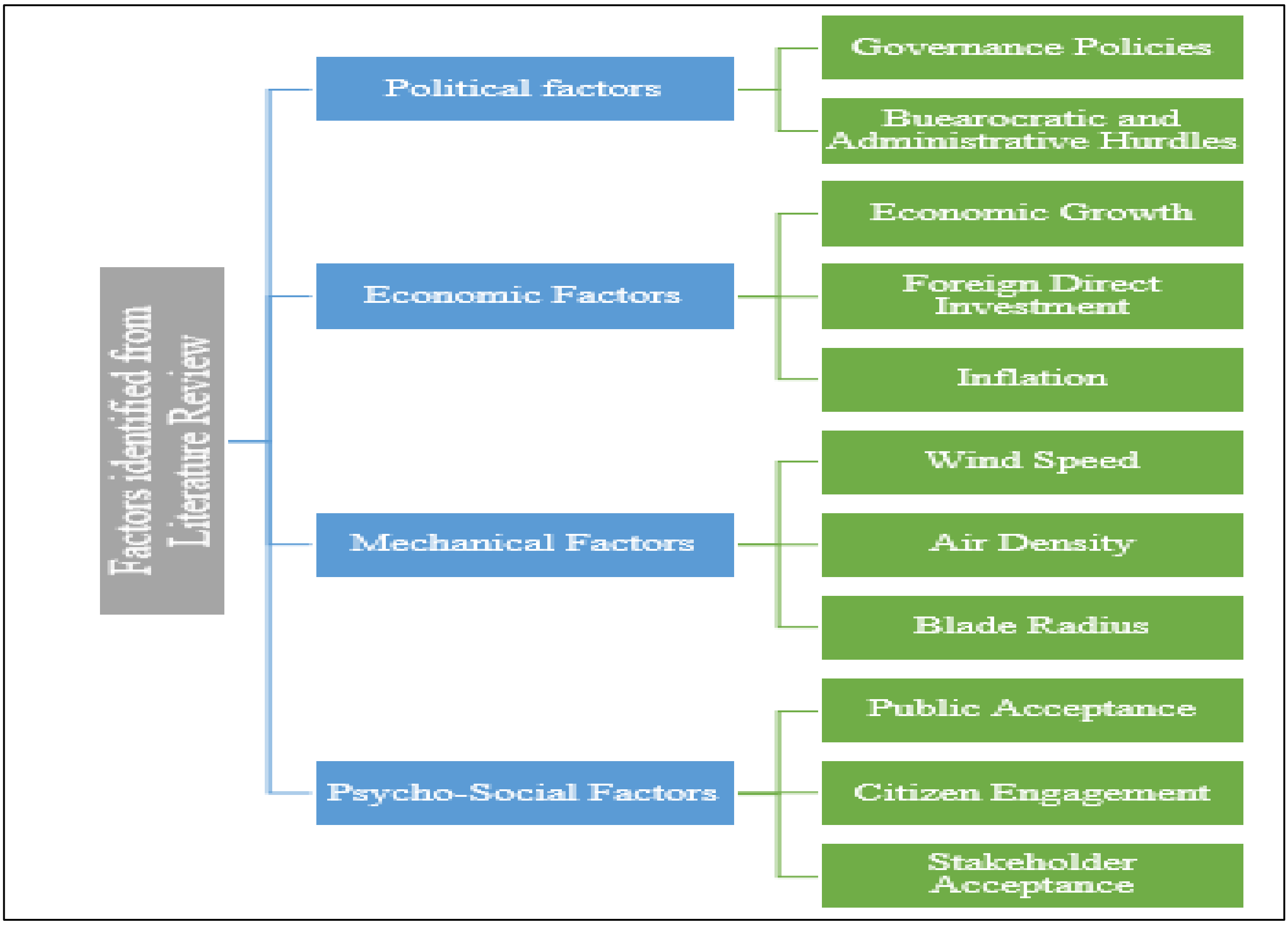

Fig 5: Factors Identified from Literature Review (Created by Author).

The establishment of a platform for engaging in meaningful dialogue between primary stakeholders, such as the fishing community, port authorities, and coastal communities, and proponents of the offshore project is of utmost importance (Solman, et al., 2021). The endorsement and advancement of offshore projects would benefit from the adoption of a unified approach by a coalition of stakeholders. This coalition typically comprises government officials, politicians, national and regional authorities, developers, and local stakeholders (Moorthy, et al., 2019).

E. Chapter Summary

This chapter presents a comprehensive overview of the relevant literature pertaining to the various factors that influence the adoption of Wind Energy Technologies for the purpose of enhancing National Energy Security. The subsequent key points are delineated beneath.

- An overview about the wind energy has been explained.
- The generation of wind energy is explained along with the parts of wind turbines.
- The relationship between the wind energy and the national energy security has been explained.
- The factors affecting the adoption of wind energy technologies for enhancing the national energy security has been explained.

➢ *The Main Factors Are:*

- Political factors
- Economic Factors
- Mechanical factors
- Psycho-Social factors

The following section pertains to the methodology section of this research.

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CHAPTER THREE
METHODOLOGY

Using positivism, objective data gathering, and deductive analysis, this quantitative research project examines operational management concerns related to wind energy technology and their effect on national energy security. In order to answer research questions about the utilisation of wind energy technology and national energy security, a survey is conducted among specialists, professionals, and stakeholders. Factor analysis is used to analyse data and expose operational management concerns with wind energy technologies and national energy security by identifying underlying variables and patterns. To optimise wind energy technologies for national security, this research methodology uses a logical progression of processes, including hypotheses, data collecting, and advanced analysis tools.

A. A Research Onion Approach

The Research Onion Model, shown in Figure 6, provides a framework for organising the research approach and process. Each layer represents a separate step in the research process and builds on the one before it. These layers are crucial for planning and carrying out the study.

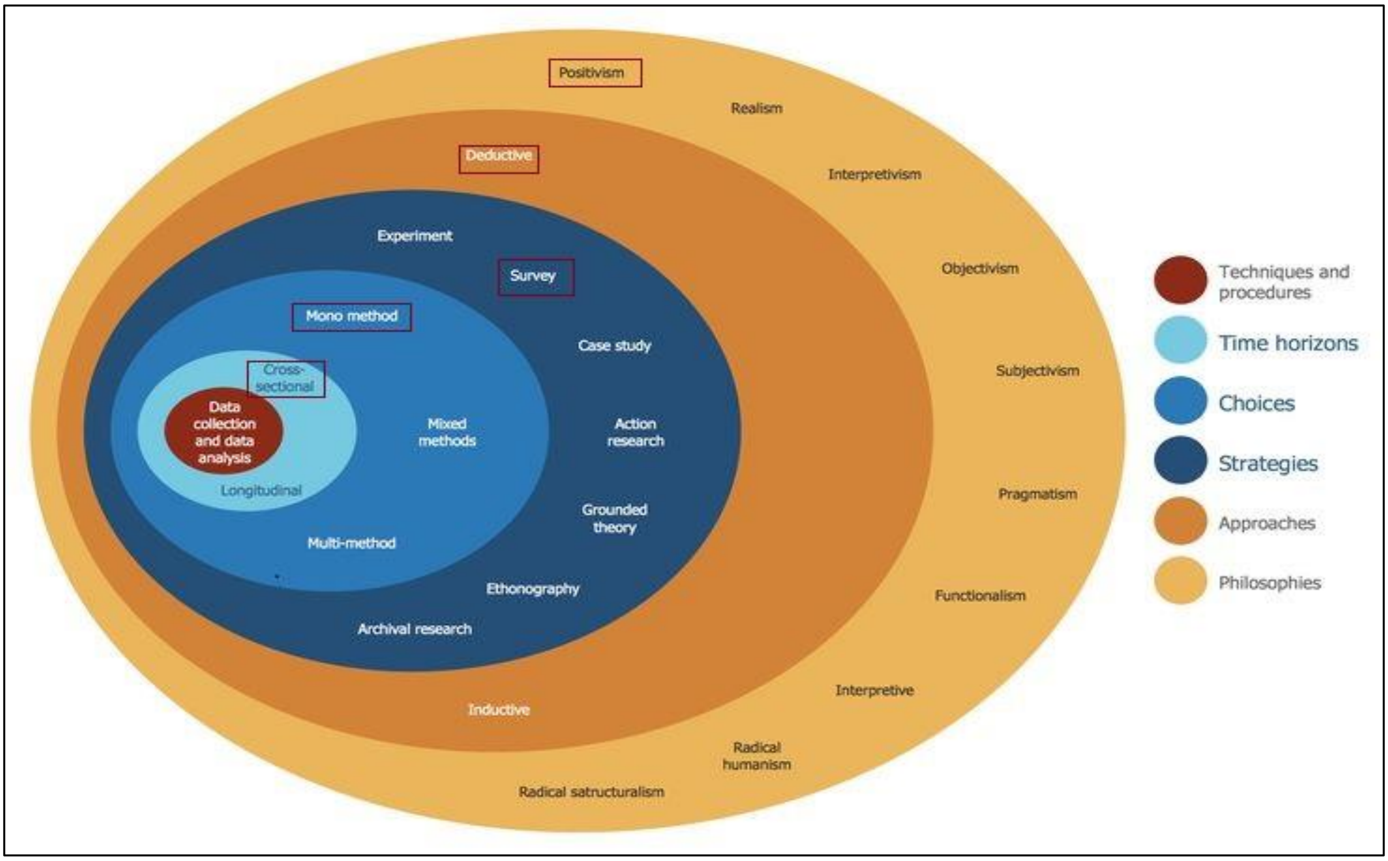

Fig 6: Research Onion Model (Created by the Author Based on (Saunders, Lewis and Thornhill, 2019))

This model provides a multi-layered framework for investigating operational management concerns related to wind generation technologies and their impact on national energy security. Each "onion" stratum of research was categorised as follows by Saunders et al. (2019)

- The first two rings reflect the inner layers, which are positively impacted and comprise the approach and guiding principles of a researcher who focuses on quantitative analysis.
- The research design, which embraces a deductive approach, is the middle layer. It includes the methodology, timescale, and study plan, with surveys acting as the main method of data gathering.
- The outer layers, which make up the "onion's core," represent the research techniques, which include feature analysis and survey-based quantitative data collection.
- Based on the research onion, the research methodology can be described as follows:

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B. Research Philosophy

A research philosophy known as positivism emphasises the use of factual data and scientific methods in the search for knowledge. This school of thought is based on the idea that methodical observation, measurement, and analysis can lead to the discovery of universal facts about the world. Given that positivism aims to identify patterns, correlations, and causal linkages among variables, it is especially well suited for quantitative research (John Dudovskiy, 2019). Positivism significantly influences the methodology for the project on operational management challenges of wind energy technologies and their effects on national energy security.

➢ *Positivism's Key Characteristics Include:*

- **Empiricism:** Positivism emphasizes empirical evidence, gathering data through surveys, experiments, and observations for analysis of wind energy technologies and national energy security (Park, Konge and Artino, 2020).
- **Objectivity:** Positivism research aims to reduce subjectivity and bias, maintaining impartiality and objectivity to support facts-based conclusions (Alharahsheh and Pius, 2020).
- **Positive Analysis:** Quantitative research uses statistical methods to analyse numerical data, drawing significant conclusions (Majeed, 2019).
- **Generalizability:** Generalizability is a goal of positivist research, which seeks to reach results that may be applied to larger populations or circumstances. (Carminati, 2018). This is significant when contemplating how wind energy technology may affect national energy security.

The project uses a positivist research perspective for data collection and analysis, focusing on quantifiable variables, surveys, and statistical techniques to assess wind energy technologies' operational management concerns and contribute to national energy security.

C. A Deductive Approach

This project uses a deductive research methodology to examine the relationship between wind energy technologies and national energy security in a disciplined and methodical manner. The research questions and objectives serve as the basis for this method's well stated theoretical foundation. By gathering and analysing quantitative data from primary sources, it tries to examine the validity of already established ideas and hypotheses. The method is crucial because it enables theoretical frameworks to be empirically validated, ensures that the study's results are based on actual observations, and increases the overall research validity (Casula, Rangarajan and Shields, 2021). Utilizing deductive reasoning, make inferences regarding the effects of wind energy technologies on energy security and the operational management concerns affecting their utilisation from the data acquired. This strategy is crucial because it combines quantitative research from a questionnaire survey with qualitative insights from a factory analysis, enabling a comprehensive analysis of the complex factors affecting the operational management of wind energy technology (Abba, Balta-Ozkan and Hart, 2022). The deductive technique offers a disciplined and logical study of the research topics while providing important insights to the field of renewable energy and energy policy through meticulous data gathering, analysis, and inference.

D. Methodological Choice

In this study, operational management concerns relating to wind energy technologies and their effects on national energy security are comprehensively investigated using a quantitative technique. Because quantitative research may produce objective, numerical data that can be statistically analysed, it is chosen as the methodology (Antwi and Hamza, 2015). To find trends, patterns, and correlations between variables, it is critical to collect structured and standardised data from a large sample size.

Data collection in wind energy technologies involves surveys or questionnaires sent to key players, including experts, policymakers, businesses, and technology providers. Quantifying responses enables statistical analysis, factor analysis, descriptive statistics, and correlations.

This study uses a quantitative methodology to provide a thorough understanding of the major operational management concerns affecting wind energy technologies and their effects on the security of the nation's energy supply. The study's findings offer insightful information that may be used to create plans for maximising wind energy technologies and boosting national energy security, eventually promoting the energy sector's resilience and sustainable growth.

E. Research Strategy

The primary technique of data collecting for this project's research plan is a survey, which is used to obtain quantitative data. The survey is made to answer the study's stated goals and research questions. Because a survey enables the systematic collection of quantitative data pertinent to the research questions and objectives, it is chosen as the main method of data collecting (Regmi et al., 2017). It is made available to key players in the field of wind energy technologies, including academics, politicians, businesspeople, and energy specialists. The survey's objectives are to evaluate how wind energy technologies affect national energy security, to identify the major operational management concerns limiting their use, and to identify the factors that contribute to these issues. The survey's questions were carefully developed to collect data in numerical form. To guarantee the accuracy and dependability of the results, the survey design aims for a representative sample. To identify significant patterns and relationships, the obtained data is analysed statistically, including factor analysis. In order to establish a model for their optimization, this research plan aims to provide a thorough understanding of the operational management difficulties associated to wind energy technologies and their role in increasing national energy security.

F. Data Collection Method

To gather data for this study, a two-pronged strategy was used: a thorough review of the literature and a structured questionnaire survey. To provide a solid knowledge, the literature review examines the current research on wind energy technology, operational management, and national energy security. For the research to expand on prior findings and identify research gaps, the literature review is crucial for establishing the context and knowledge base. This ultimately increase the study's credibility and relevance (Snyder, 2019). The purpose of the questionnaire survey is to compile quantitative information from key players in the wind energy industry. It primarily focuses on the stated study topics, evaluating how people perceive the effect of wind energy on energy security, highlighting significant operational management challenges, and identifying variables affecting these issues. The questionnaire survey is an essential technique because it engages stakeholders and industry experts directly, enables the collection of precise quantitative data on perceptions and other associated variables, and offers a solid analytical and decision-making foundation (Laugé, Hernantes and Sarriegi, 2015) . Through the use of improved wind energy technologies, this integrated strategy intends to increase national energy security by supplying a solid dataset for the development of factor analysis-based models.

➢ *Primary Data Collection Method*

To gather data for this project, a questionnaire survey using the Qualtrics platform is used. Participants in the survey, which also includes staff members, MBA students, International Business Management (IBM) students, and academic researchers, asked to provide primary quantitative data.

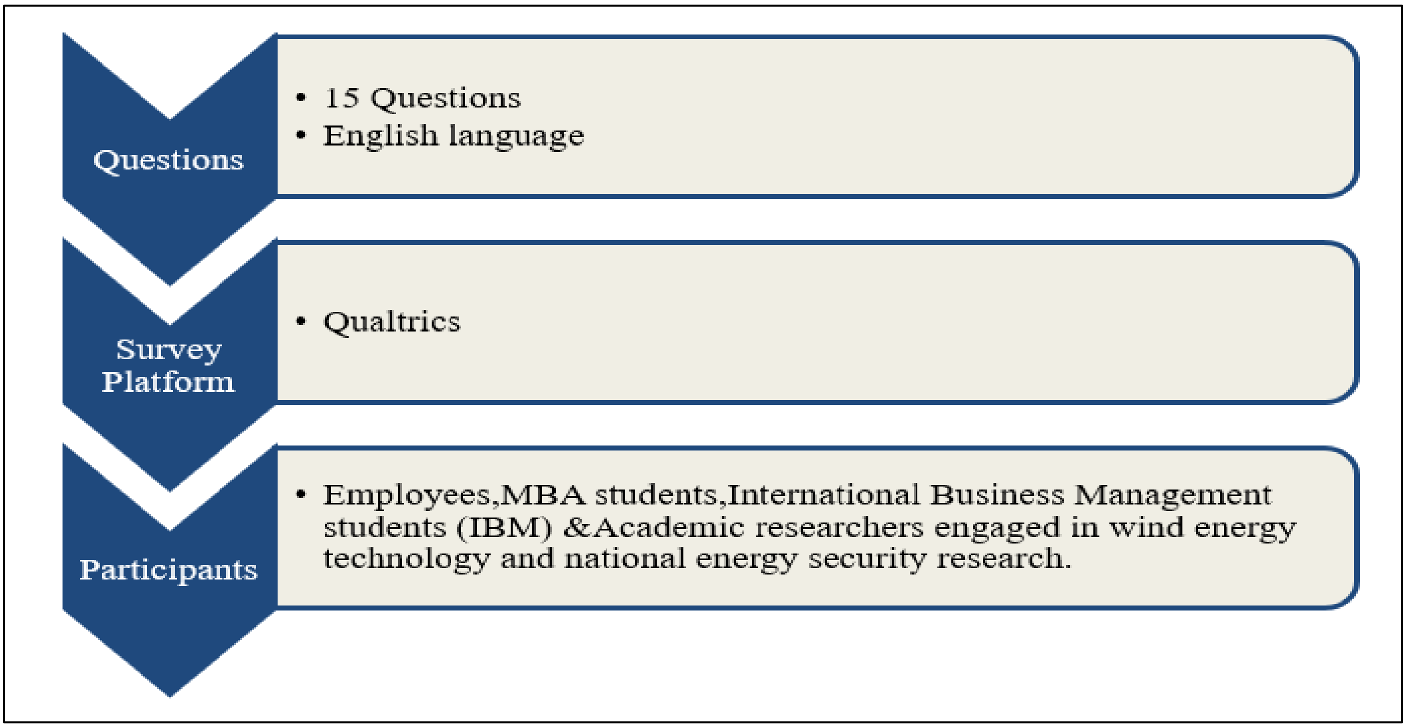

Fig 7: Questionnaire Design (Created by the author)

There are 15 questions in the survey that are intended to address the study's goals. These inquiries look at how wind energy technologies affect concerns with operational management and national energy security, as well as important factors that influence these issues.

A factor analysis-based model is developed to optimise wind energy technologies for boosting national energy security, and the poll is crucial for providing informative data that is used in this process. To create a factor analysis-based model, the survey collects data and viewpoints from the real world.

The survey is crucial in providing insightful information to build a factor analysis-based model that would optimise wind energy technologies for increasing national energy security. The survey gathers data and opinions from the real world, laying the framework for a model based on factor analysis (Wu et al., 2022).To obtain thorough insights, a sample size of 100 respondents was selected to provide a representative sample of people. Figure 7 shows the questionnaire's format, including the total number of questions, the survey platform of choice (Qualtrics), and the intended audience.

- **Sample Size:** The author sent out the survey form to 120 individuals and out of which 96 were responded and it became the sample size. The sample was collected using a snowball sampling in which the respondents themselves spreads the survey like a snowball.

➢ *Secondary Data Collection Method*

For this project, the literature study entails a thorough investigation of the body of knowledge and scholarly writing on wind energy technologies, their effect on national energy security, and the difficulties in operational management they encounter. To get a solid comprehension of the subject, a thorough examination of the pertinent literature is necessary.

Table 1: Criteria for Including and Excluding Articles (Created by the Author)

Inclusion Criteria	Exclusion Criteria
Research articles published from the year 2015 onwards.	Papers published before 2015.
Articles specifically focused on wind energy technologies.	Research unrelated to wind energy technologies or national energy security.
Papers that discuss the impact of wind energy on national energy security.	Non-peer-reviewed sources.
Studies that address operational management issues related to wind energy technologies.	Language other than English.
	Duplicates or redundant studies.

To access a wide selection of peer-reviewed articles, research papers, and scholarly publications, respected academic databases like Google Scholar and Scopus are used for secondary data collection. These websites act as the main resources for locating pertinent studies and locating reliable information. Table 1 lists the inclusion and exclusion criteria for the articles to guarantee the selection of the most pertinent and latest research publications.

G. Factor Analysis using SPSS Software

Factor Analysis, a statistical method made available by IBM's SPSS software, is used in this research project's data analysis to find hidden links and patterns in the quantitative data that was gathered. This approach was adopted to explore the interactions between various variables and gain a greater knowledge of the complicated elements influencing operational management problems for wind energy technology. In SPSS, factor analysis is used to discover complex correlations between variables (Shrestha, 2021a). A strong foundation for creating a model for wind energy technology optimization, factor analysis is particularly effective for finding underlying issues that may affect national energy security. Applying this method enables one to gain insightful information that advances national energy security while also supporting the main goals of the study.

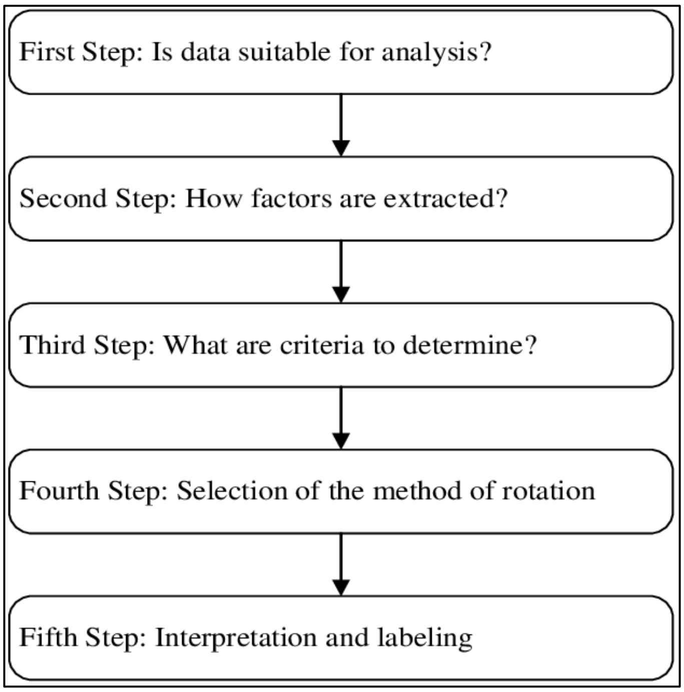

Fig 8: Steps Involved in Factor Analysis (Created by the Author)

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The steps in factor analysis, which are depicted in Figure 8, act as a systematic framework that makes it possible to identify latent variables and relationships that affect the operational management difficulties of wind energy technologies, resulting in recommendations for the improvement of national energy security that are well-informed.

➢ *In 2021, Shrestha Outlined the Essential Stages of Factor Analysis as Follows:*

- Initial Data Preparation: Compile pertinent information on operational management challenges and wind energy technologies, making sure the dataset is accurate and fit for analysis.
- Choosing the Factors: Based on the research goals and objectives, identify the latent factors that might be causing the data correlations that were found.
- Factor Extraction: To separate the latent factors from the observable data, use statistical methods. Methods like Principal Component Analysis (PCA) or Common Factor Analysis are used in this step (CFA).
- Factor Rotation: Refine the variables to make them easier to interpret and their relationships simpler.
- Interpretation: Consider operational management challenges and national energy security when analysing the rotated components to grasp their underlying significance.
- Model Development: Create a model based on the Factor Analysis findings with the goal of maximising wind energy technologies for the improvement of national energy security.

H. Ethical Consideration

Ethical considerations were strictly followed throughout the course of this main data-driven quantitative research endeavour. All required clearances were obtained from a recognised ethical committee before the poll was launched, ensuring that the research followed the tight criteria and standards established by the university. To ensure conformity with university norms and ethical principles for research integrity, ethical approval from a respected committee was acquired (Drolet et al., 2023). The poll and its implementation were carefully planned to avoid harming any of the participants, and respondents' privacy and confidentiality were strictly upheld. Maintaining trust, protecting sensitive data, and upholding study integrity require ensuring ethical concerns and participant well-being (Bhandari., 2021). The research was conducted with the utmost integrity and respect for the participants by adhering to the ethical principles of openness, informed consent, and confidentiality at all phases of the process.

I. Chapter Summary

The project's methodology chapter sought to thoroughly evaluate operational management concerns regarding wind energy technologies and their influence on global energy security. From this chapter, the following summary and conclusions are drawn:

- A primary data-driven approach was used, primarily relying on quantitative research techniques.
- The primary instrument for data collection was a well-designed questionnaire survey targeting stakeholders in the wind energy sector.
- Factory analysis was conducted in addition to the survey to provide real-world context and practical insights.
- The proactive approach to primary data collection ensured a comprehensive understanding of operational management challenges.
- Quantitative research methods identified and analysed key issues in wind energy technology management.
- The methodology provided a strong foundation for subsequent analysis and discussion.

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CHAPTER FOUR
FINDINGS

This section discusses the importance of using statistical methods for the analysis of primary data. Exploring the first stage, or descriptive analysis, is where it starts. During this first stage, various dataset properties are summarised and visualised in order to get a crucial understanding of the dataset's main tendencies, distributions, and overarching patterns. The emphasis shifts to factor analysis, a later stage that aims to reveal underlying correlations and latent factors in the data. This work tries to illuminate these approaches in order to clarify the dynamic interaction between descriptive analysis and factor analysis.

A. Descriptive Analysis of Factors Influencing the Operational Management Issues on the Wind Energy Technologies on National Energy Security

The acceptance of 96 out of the 120 invitations distributed shows that the thesis author achieved a commendable response rate. Maintaining a high or substantial response rate in research surveys is the most important thing to do to make sure that the results are reliable and useful and that they accurately reflect the intended demographic. It is important to acknowledge that the process of selecting the sample was carried out using convenience sampling, a method that does not adhere to statistical principles. In addition to the mentioned Formula 4.1, an alternative methodology is utilised for the computation of the proportion of participants who have provided their responses.

$$Response\ Rate\ (RR) = \frac{Total\ attributed\ Conversions}{Total\ Unique\ Users} \times 100 \quad (4.1)$$

$$RR = \frac{96}{120} \times 100 = 80\%$$

The survey's 80% response rate demonstrates its effectiveness in generating active involvement and validating its well-structured design. This high response rate strengthens data reliability and connects with a majority of participants, indicating its ability to capture diverse viewpoints and inform decision-making.

Table 2: Descriptive Statistics of Survey Findings (Created by Author According to SPSS result)

	Mean	**Std. Deviation**	**Variance**	**Skewness**	**Kurtosis**	**N**
Governance factors	2.65	1.32	1.751	.124	-1.199	96
Bureaucratic and administrative	2.76	1.231	1.516	.124	-.885	96
Hurdles						
Economic growth	2.80	1.389	1.930	.098	-1.139	96
Foreign Direct Investment	2.99	1.246	1.522	.152	-.858	96
Inflation	2.98	1.260	1.587	-.024	-.861	96
Wind Speed	3.08	1.274	1.622	.028	-.970	96
Air Density	3.19	1.164	1.354	-.067	-.695	96
Blade Radius	3.14	1.284	1.649	-.123	-.964	96
Public Acceptance	2.94	1.200	1.440	.010	-.654	96
Citizen Engagement	3.09	1.085	1.177	-.087	-.680	96
Stakeholder Acceptance	3.57	1.184	1.402	-.592	-.302	96
Valid N(listwise)						96

The table 2 above provides statistical descriptions of the variables affecting the adoption of wind energy technologies. Survey results reveal factors impacting wind energy technology use in operational management, including governance, bureaucracy, economic growth, investment, inflation, and stakeholder acceptance.

The survey participants' perspectives of the various elements impacting the adoption of wind energy technology are highlighted by the mean values collected from the survey respondents. Stakeholder Acceptance has the highest mean value of these characteristics, 3.57, suggesting that it is thought to have a Very High Impact on the adoption process. This outcome highlights how important stakeholder acceptability is to the advancement of wind energy technologies. Additionally, with mean values of 3.19 and 3.14, respectively, denoting High Impact, Air Density and Blade Radius also show up as important components. These conclusions highlight the significance of taking stakeholder acceptance into account in addition to technical considerations when attempting to manage operations effectively. On the other hand, characteristics including public acceptance, bureaucratic and administrative challenges, and governance factors have mean values between 2.65 and 2.94, indicating a Moderate to Low Impact. These findings imply that while these considerations are acknowledged, they may have a relatively less impact on decisions about the adoption of wind energy technologies.

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The results of the Likert scale study point to Moderate Impact for the variables influencing the adoption of wind energy technology. Factors with a mean value of 3 have moderate impact on adoption, with all values exceeding 3. The standard deviations, which range from 1.085 to 1.389, represent the distribution of the data around the means. While economic growth has a larger standard deviation of 1.389 and predicts greater response variability, factors like citizen engagement show a lower standard deviation of 1.085 and suggest a more focused dataset.

Skewness gauges the asymmetry of a distribution's behaviour around its mean, with a value of 0 denoting a symmetrical distribution. Positive skewness suggests a longer tail on the right side, whereas negative skewness shows a longer tail on the left side. Kurtosis, which assesses the data's tail concentration, is frequently compared to the kurtosis of a normal distribution. Excess kurtosis is derived by deducting 3 from the kurtosis value; positive excess kurtosis indicates heavier tails and sharper peak, while negative excess kurtosis indicates lighter tails and a flatter peak. Skewness and Kurtosis Normal Ranges is -2 to +2.

B. Assessment of Factor Analysis for Enhancing Wind Energy Technology and Strengthening National Energy Security Coding

The important step of coding came first in the study's factor analysis method, ensuring that the data was precisely organised for in-depth analysis. A sample of 96 out of a total of 120 participants in the study provided their insightful opinions, representing a great response rate of 80%. The exploration of participant perceptions of the many elements influencing the adoption of wind energy technology is made possible by the use of a Likert scale, with a score of 3 denoting moderate impact.

The factor analysis procedure is being rigorously carried out using the statistical programme SPSS 27, revealing complex correlations between the variables. The capabilities of the software enabled a thorough and intelligent study of the data, increasing the accuracy of the research (Reinholz et al., 2021).

In addition, the study was supported by a thorough literature review analysis that made it possible to identify and comprehend the primary elements influencing the uptake of wind energy.

Table 3: Likert scale Response Rate
(Created by author according to SPSS result)

Options	Value
Very High Impact	5
High Impact	4
Moderate Impact	3
Low Impact	2
Very Low Impact	1

- *KMO and Bartlett's Test*

A statistical method for evaluating the suitability of the sample size for factor analysis is the Kaiser-Meyer-Olkin (KMO) measure (Shrestha, 2021b). Through comparing their common variance, it assesses the degree to which variables in a dataset are amenable to study. The KMO value goes from 0 to 1, and higher values (preferably over 0.5) signify that the data are more suitable for factor analysis. In SPSS, factor analysis is a statistical technique used to find underlying trends and connections in a dataset (Schreiber, 2021). Tools for conducting exploratory factor analyses (EFA) or confirmatory factor analyses (CFA) are available in SPSS (Statistical Package for the Social Sciences). While CFA examines predetermined models, EFA tries to identify latent factors that account for relationships between observed data (Phakiti, 2018). With the help of SPSS, researchers can investigate complex data structures and comprehend the underlying dimensions influencing their variables. These capabilities include data reduction, factor extraction, rotation, and interpretation.

The KMO assesses sampling adequacy, which establishes whether the responses provided with the sample are sufficient or not. To successfully do factor analysis, this value needs to be near 0.5. According to Kaiser, levels between 0.7 and 0.8 are acceptable, values above 0.9 are excellent, and values as low as 0.5 (the KMO value) are barely acceptable.

Table 4: KMO and Bartlett's Test (Created by Author According to SPSS Result)

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		.709
Bartlett's Test of Sphericity	Approx. Chi-Square	313.005
	Df	55
	Sig.	.000

Kaiser-Meyer-Olkin (KMO) tests are shown in Table 3, A KMO score greater than 0.5 denotes strong enough correlations between the variables to support the extraction of underlying factors. The KMO score of 0.709 in this instance indicates a high level of sampling adequacy.

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Bartlett's Test of Sphericity yields a 313.005 chi-square value and a Sig. of 0.000, indicating the dataset is suitable for factor analysis. The alternative hypothesis of the correlation matrix being an identity matrix is rejected, indicating the dataset is unsuitable for factor analysis.

- *Principal Component Analysis (PCA)*

A group of 11 subfactors collected from a survey are the subject of investigation, which makes use of Principal Component investigation (PCA). Through the study, these subfactors were further separated into three different components. In order to determine the ideal number of components to retain in the PCA method, researchers are considering extracting these components using a criterion where eigenvalues greater than 1 are considered important.

Table 5: Principal Component Analysis (Created by Author According to SPSS Result)

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.136	28.512	28.512	3.136	28.512	28.512	2.670	24.268	24.268
2	2.500	22.725	51.238	2.500	22.725	51.238	2.058	18.707	42.975
3	1.056	9.605	60.842	1.056	9.605	60.842	1.965	17.867	60.842
4	.856	7.781	68.623						
5	.727	6.613	75.236						
6	.655	5.955	81.191						
7	.605	5.503	86.694						
8	.499	4.535	91.230						
9	.397	3.611	94.840						
10	.337	3.066	97.906						
11	.230	2.094	100.000						
Extraction Method: Principal Component Analysis									

According to PCA analysis three components are extracted based on their eigenvalues.

Principal component analysis uses eigenvalues to rank the significance of principal components, reducing dimensionality while retaining information and selecting informative dimensions for analysis.

The Initial Eigen Values, Extracted Sums of Squared Loadings, and Rotation of Sums of Squared Loadings components of the Eigenvalue table are divided into three groups. The study focuses on initial eigenvalues and extracted sums of squared loadings, calculating the total number of components using 11 variables. The first component has values of 3.136, 2.500, and 1.056, while the extracted sum of squared loadings accounts for 28.512%, 22.725%, and 9.605% of variation.

The eigenvalues are plotted against each element in a graph called a scree plot (Ledesma, Valero-Mora and Macbeth, 2015). Using the graph makes calculating how many factors to keep simpler. Where the curve begins to flatten is the key point of interest. The scatter plot of the results is depicted in figure 9 below, which highlights the components with Eigen values greater than 1. A screen plot shows eigenvalues plotted against their associated principal component (PC) number graphically. Identifying the point on the graph where a discernible change in the slope is detected allows one to estimate the retention of PCs.

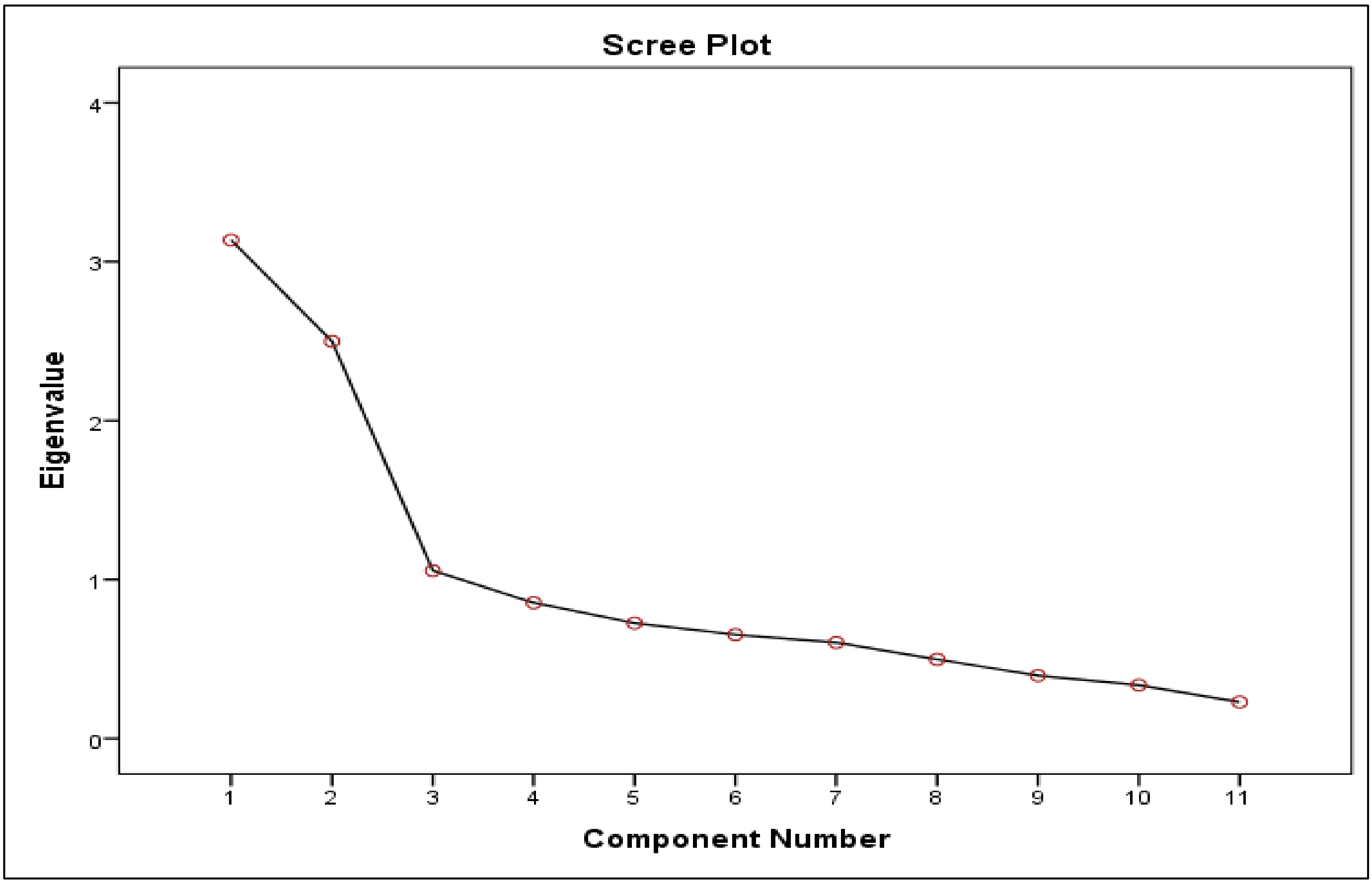

Fig 9: The Scree Plot of Findings (Created by author according to SPSS result)

Figure 9 displays the scree plot used in factor analysis. The author used SPSS to build this graph to study the trend of decreased variety that each following element generates Scree plots count primary components and display eigenvalues for each component, creating a component matrix on the x and y axis.

➢ *Component Matrix*

Table 6 shows the loadings of the 11 variables on the three extracted components. Cross-loading factors in factor analysis are variables with significant loadings on a number of components. The structure and interpretation of the elements are made clearer by removing cross-loading factors.

Table 6: Component Matrix (Created by Author According to SPSS Result)

	Component		
	1	**2**	**3**
Governance Factors		.693	
Bureaucratic and aministrative hurdles		.691	
Economic growth	.506	.450	
Foreign Direct Investment		.503	
Inflation	.465	.596	
Wind Speed	.655	-.432	
Air Density	.614	-.436	.421
Blade Radius	.641		
Public Acceptance	.584	-.447	-.482
Citizen Engagement	.559		.509
Stakeholder Acceptance	.639		
Extraction Method: Principal Component Analysis.			
a. 3 components extracted.			

After cross-loading factors are eliminated, the rotational component matrix is updated, and this new version offers a more realistic depiction of the connections between variables and underlying factors. Thus, the results of the factor analysis are more trustworthy and easier to understand.

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➢ *Rotated Component Matrix*

The rotated component matrix was rotated using the Varimax method and then normalised using the Keizser method.Based on Pearson correlation scores, the distribution of subfactors within each category was selected. Notably, the fundamental correlation value shows significant strength. In this case, the greatest Pearson correlation value which runs from -1 to +1 was used to assess the link between the variables. Zero shows that there is no correlation between the two variables. When the value is between 0 and 1, it denotes a positive correlation, a directly proportional relationship; when one variable rises, the other does too. In contrast, when the number falls between 0 and -1, it denotes a negative correlation, where a rise in one variable is accompanied by a fall in the other. An inversely proportionate relationship is implied by this negative correlation.

Table 7: Rotated Component Matrix (Created by Author According to SPSS result)

	Component		
	1	**2**	**3**
Governance factors	.742		
Bureaucratic and administrative hurdles	.787		
Economic growth	.646		
Foreign Direct Investment	.639		
Inflation	.751		
Wind Speed		.776	
Air Density			.822
Blade Radius			.684
Public Acceptance		.862	
Citizen Engagement			.768
Stakeholder Acceptance		.602	
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.			
a. Rotation converged in 4 iterations.			

The subfactors in table 7 is Pearson correlations greater than 0.4, those subfactors are given positive values in the rotational component matrix. The rotated component matrix is used to figure out the connections between particular components. If the Pearson correlation values for three particular components in the results exceed 0.4, a positive correlation has occurred.

➢ *Component 1-Economic Indicators*

In this study, variables must show correlations of 0.4 or more. The first component is Economic indicators. All of the component matrix's variables post-rotation exhibit positive loadings, improving interpretability.

- Governance factors (.742)
- Bureaucratic and administrative hurdles (.787)
- Economic growth (.646)
- Foreign Direct Investment Inflation (.639)
- Inflation (.751)

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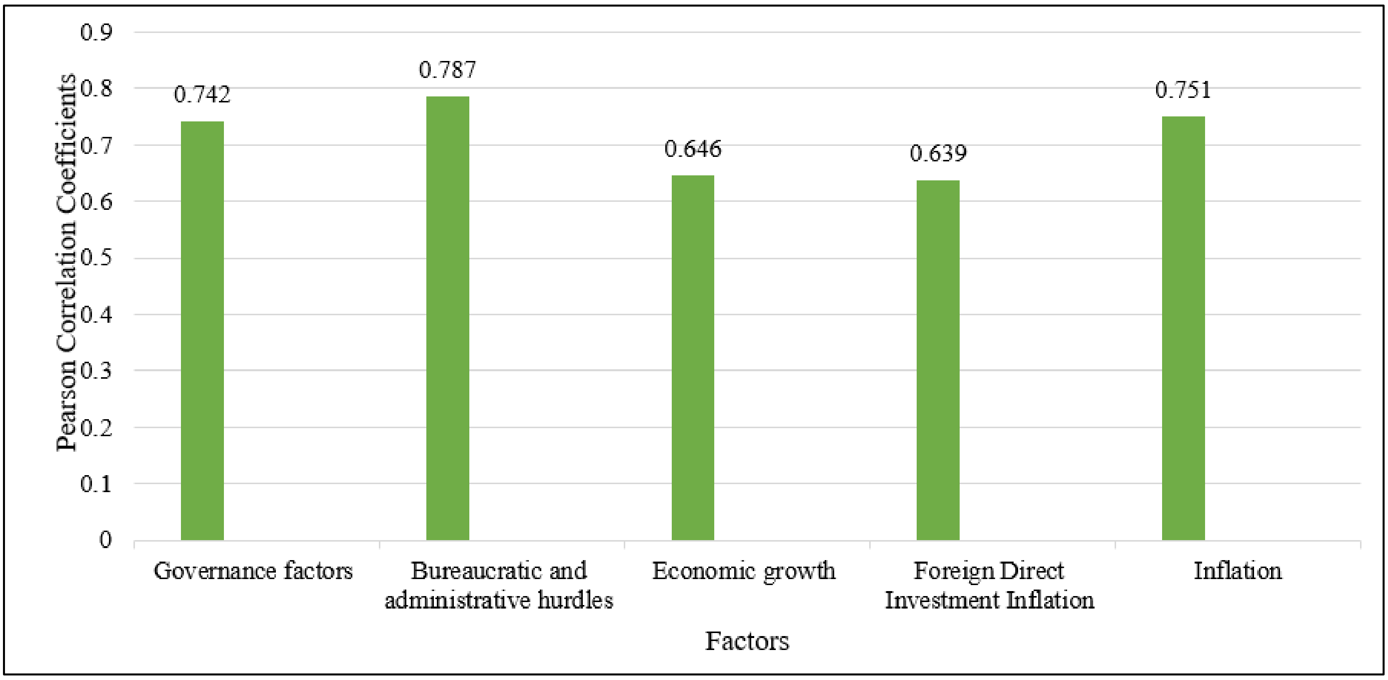

Fig 10: Economic Indicators (Created by Researcher)

The component 1 factors are shown in figure 10. The fact that the components are clustered under Component 1 effectively suggests that variables with significant loadings on these factors share an underlying influence.

➢ *Component 2-Renewable Energy Engagement Factors*

Based on its factor loadings as shown in the rotated component matrix (table 6), the second component can also be referred to as Renewable Energy Participation Indicators.

- Wind Speed (.776)
- Public Acceptance (.862)
- Stakeholder Acceptance (.602)

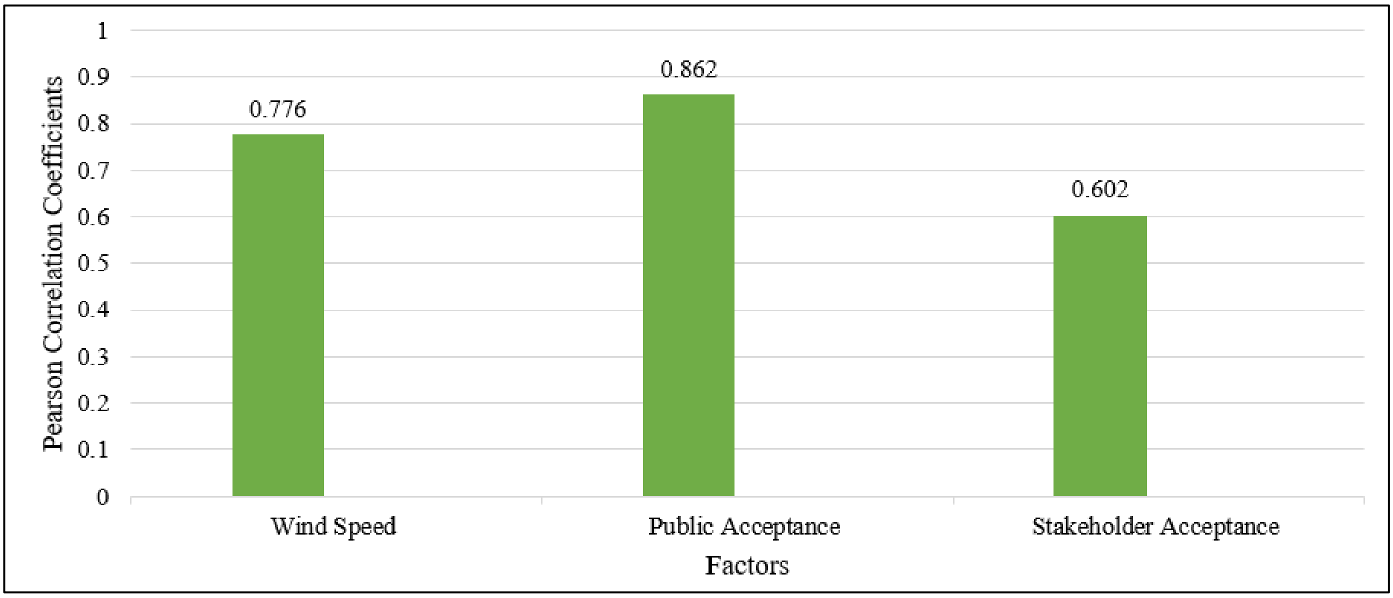

Fig 11: Renewable Energy Engagement Factors (Created by researcher)

All of the variables in the component matrix now have positive values after the rotation operation. The component 2 factors are shown in figure 11 as follows. Based Descriptive Analysis of Factors Influencing the Operational management issues for adoption and application of wind energy technologies.

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➢ *Component 3-Wind Energy Performance Parameters*

The third component, known as wind energy performance parameters, can be recognised based on the loadings in the rotational component matrix. After the rotation is finished, every variable in the component matrix has positive values, which effectively draws attention to the third component's qualities. The component 3 factors are shown in figure 12 as follows.

- Air Density (.822)
- Blade Radius (.684)
- Citizen Engagement (.768)

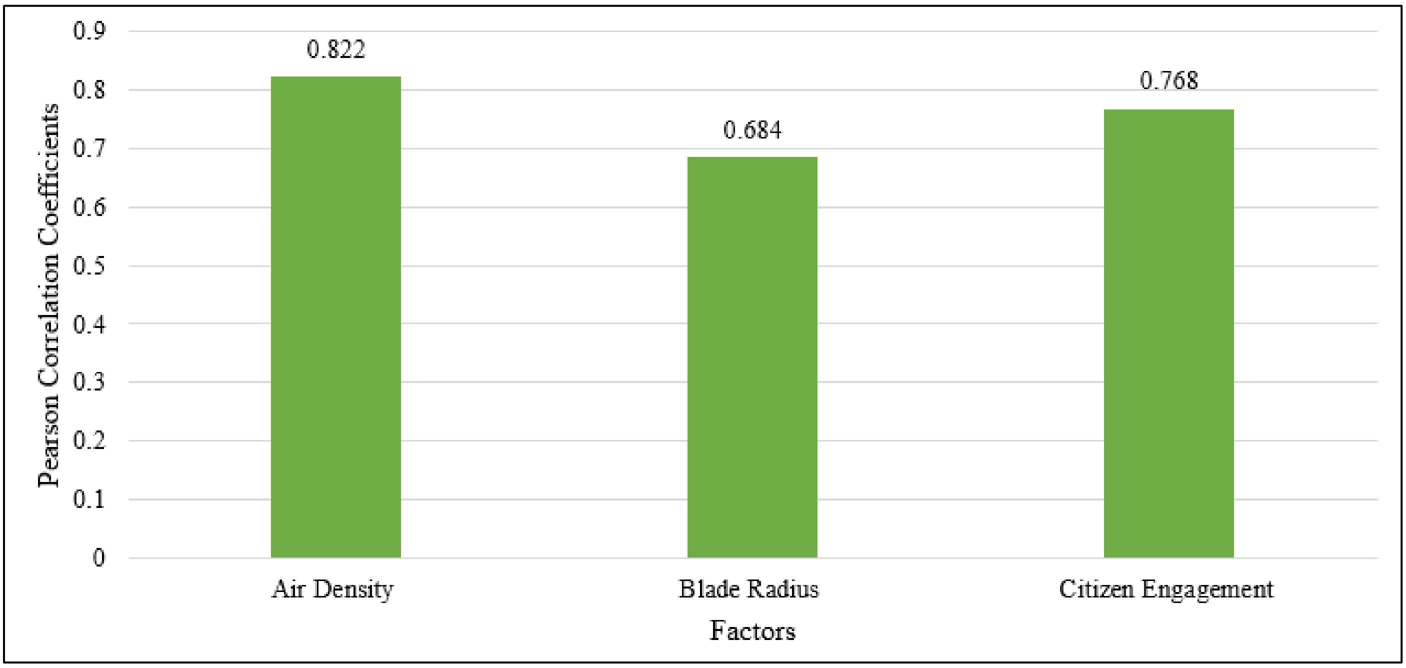

Fig 12: Wind Energy Performance Parameters **(**Created by Researcher)

The component 3 factors are shown in figure 12 as follows, Operational management factor analysis for the optimisation of wind energy technologies for the strengthening of national energy security.

C. Chapter Summary

This section explores statistical methods for analysing primary data, beginning with descriptive analysis to understand trends.

- In the following stage, factor analysis, the goal is to identify hidden factors and underlying correlations. This study clarifies how descriptive analysis and factor analysis interact. An impressive 80% of respondents responded to the survey, demonstrating its validity.
- The adoption of wind energy is affected by many factors, which are shown by descriptive statistics. Along with air density and blade radius, stakeholder acceptance is found to be quite important. Impact is mild, according to a Likert scale study.
- The principal component analysis (PCA) finds three key components. Correlations are made clear by the Rotated Component Matrix, which also produces components for wind performance and renewable energy.

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CHAPTER FIVE
DISCUSSIONS

A. Introduction

A comprehensive study of the findings from the factor analysis is covered in this section. According to descriptive data, the study's primary focus is on the nuanced elements that affect the adoption of wind energy. Air density, blade radius, and stakeholder acceptance stand out among these variables as crucial. Notably, the study uses a Likert scale assessment to determine the impact of these characteristics, which shows a moderate impact. Three important components are discovered by principal component analysis (PCA). By highlighting components relevant to wind performance and renewable energy, the rotated component matrix clarifies relationships and highlights linkages. These findings highlight the complex interrelationships among various variables, promoting a thorough comprehension of the dynamics of wind energy adoption.

B. Harmonizing Research Discoveries with Objectives

The three crucial components and the 11 related subfactors are examined in depth in this extensive study of operational management issues in the context of wind energy technologies. The main goal is to coordinate new scientific findings with the broad objective of enhancing national energy security.

➢ *The Uses of Wind Energy Technologies on the National Energy Security*

The global shift towards cleaner energy sources is transforming electricity generation, with variable renewable generation technologies expanding rapidly. Reduced costs and legislative support are the driving forces behind this growth. As nations align their energy agendas with climate change mitigation goals, the trend is expected to continue or worsen (Cassuto, 2018).

Conventional power generation techniques, like coal, nuclear, and hydroelectric, are stagnating. Clean energy sources are leading global energy transformation, but strategic policies are needed for smooth transition.

Renewable energy faces challenges due to distributed, decentralised sources, cyberattacks, and reliance on rare metals and minerals, which are scarce or controlled by a few nations (Majid, 2020). Strong cybersecurity measures are crucial for protecting energy infrastructure. Energy security refers to dependable, unhindered access to energy supplies, ensuring availability and affordability. Laos' vulnerability assessment and action plan for enhancing energy system resilience serve as evidence of the beneficial relationship between resilience and energy security (Cox et al., 2019). Energy security is a top priority, while resilience enhances adaptability to changing conditions and recovery from disruptions. Economic expansion, extreme weather, and cyberattacks increase energy system vulnerability, emphasizing the need for strategic planning and understanding new technologies to ensure resilience.

Utilising wind energy technology can significantly improve national energy security. Wind energy expansion helps with diversification, lessens reliance on conventional power plants, and reduces environmental concerns as the world's energy landscape shifts to clean sources. Challenges like mineral dependency and cyber vulnerabilities, however, require cautious thought. Nations can traverse this transformational path deliberately and guarantee a stable and sustainable energy future by establishing a complex balance between energy security and resilience.

Utilising wind energy technologies to secure national energy is likely to have significant practical effects. In the first place, wind energy diversifies the energy mix, lessening reliance on fossil fuels and susceptibility to supply disruptions. Long-term energy stability is promoted by the switch to renewable energy sources. Energy independence is further strengthened through investments in wind energy projects that foster economic expansion and employment development. Effective operational management techniques in wind power facilities increase dependability and resilience while providing protection against unforeseen difficulties. Overall, including wind energy in a country's energy mix is an essential step towards developing sustainable, secure, and independent energy systems.

➢ *The Main Operational Management Issues that Affect the Application of Wind Energy Technologies*

There are numerous benefits associated with wind energy, which is one of the energy sources that is expanding the fastest on a global scale. However, the imperative requirement to successfully solve a variety of operational management issues sheds light on the path to its continued success.

The problem of rivalry with alternative energy sources is one of several issues that require addressing. Wind projects encounter challenges in terms of cost competitiveness, particularly in areas with insufficient wind resources (Li et al., 2014). In order to address this, ongoing technological and manufacturing process improvements as well as a deeper comprehension of the complex physics governing wind plant operations are necessary.

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Table 8: Operational Management Issues that Affect the Application of wind Energy Technologies (Created by Researcher)

Management Issues	**Functions**	**Citations**
Competition with Other Energy Sources	Wind projects may struggle in low wind resources, but cost savings may be possible with improved manufacturing techniques, technology, and understanding of turbine physics. Competition from natural gas and solar energy may drive cost reduction and performance improvements.	(Li, et al., 2014) (Ahmed, et al., 2020)
Carbon Footprint	Offshore wind turbines produce carbon dioxide emissions from manufacturing, installation, operation, and decommissioning, involving fossil fuel combustion and ongoing maintenance, despite efforts for carbon-neutral alternatives.	(Kaldellis & Apostolou, 2017) (Wang, et al., 2022) (Gao, et al., 2021)
Safety Concerns	Offshore wind projects expand beyond nearshore sites, causing increased costs and risks. Employers must ensure worker safety by implementing workplace hazards and promoting knowledge and skills. Wind turbines have a commendable safety record but are susceptible to failures like blade icing, ice shedding, and blade throw.	(Karasmanaki, 2022) (Slaven & Dennis, 2012 (Kelsey, 1994) (Hammond, et al., 2021) (Abdullah, et al., 2023)
Infrastructural and Logistical Challenges	The wind industry's infrastructure involves manufacturing and installation processes for turbines, including location, design, material procurement, assembly, connection, and maintenance. Implementing streamlining measures can increase cost-effective access to wind energy.	(Gabriel, 2016) (Office of Energy Efficiency and Renewable Energy, 2023) (Arshad & O'Kelly, 2019

The operational management issues in wind energy technologies are shown in Table 8. The research, which examined operational management issues in wind energy technologies to improve national energy security, has significant practical ramifications. First off, it emphasises the importance of funding R&D to boost the effectiveness and dependability of wind energy technology, providing a more resilient energy system. Renewable energy initiatives need to be managed effectively along the supply chain and through strategic alliances with component suppliers to avoid delays and cost overruns. In addition, putting a focus on skill development and workforce training helps equip experts to operate and maintain wind energy systems successfully, lowering operational risks. It aims to contribute to the sustainable growth of wind energy, improve a country's energy security, and minimise environmental damage by addressing these practical aspects.

➢ *Factors Influencing the Functioning of Wind Energy Technologies*

A thorough assessment of the literature led to the identification of 11 different criteria. These factors were carefully examined using factor analysis, which resulted in the identification of three main factors and related subfactors, shedding important light on the subject of this study. The study employed factor analysis on survey data, revealing three principal components from 11 subfactors. Using SPSS 27, a Likert scale, achieving an 80% response rate. The principal component analysis identified the key dimensions. After eliminating cross-loading factors, a Varimax rotation highlighted strong positive correlations among governance, bureaucratic hurdles, economic growth, foreign direct investment, inflation, wind speed, air density, blade radius, public acceptance, citizen engagement, and stakeholder acceptance.

This comprehensive analysis contributes valuable insights into the factors influencing the adoption of wind energy technology, strengthening national energy security and sustainability. Several practical consequences emerge from this initiative, which is centred on assessing the variables impacting the performance of wind energy technologies to improve national energy security. First of all, understanding the effects of weather variability highlights the necessity for sophisticated weather forecasting systems that will ensure stable grids and effective use of wind resources. Implementing smart grid technology and energy storage solutions is a realistic way to address grid integration, increasing the dependability of wind energy as a continuous power supply and greatly boosting national energy security. Effective operational maintenance procedures directly affect downtime, operational costs, and wind turbine lifespan, ultimately boosting the wind turbines' overall efficiency and resilience.

Effective supply chain management for procuring essential parts and supplies promotes project continuity, reduces potential delays, and aids in cost management. Promoting favourable laws and regulations can encourage the development of the wind energy industry, encourage long-term expansion, and enhance both environmental and energy security. Finally, investing in qualified personnel through training and development programmes assures competent operation and maintenance of wind energy systems, a crucial component in fulfilling the initiative's goals. Together, these doable actions strengthen the desire to improve national energy security using wind energy technologies. The elements generated from the findings of the factor analysis are thoroughly covered in the following sections:

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C. Model for Factor Analysis-Driven Optimization of Wind Energy Solutions for National Energy Security

Analysis reduces research dimensionality by narrowing variables to economic indicators, renewable energy engagement factors, and wind energy performance parameters. This approach improves operational management, optimises economic indicators, and enhances wind energy performance parameters, enhancing wind energy technology adoption and application.

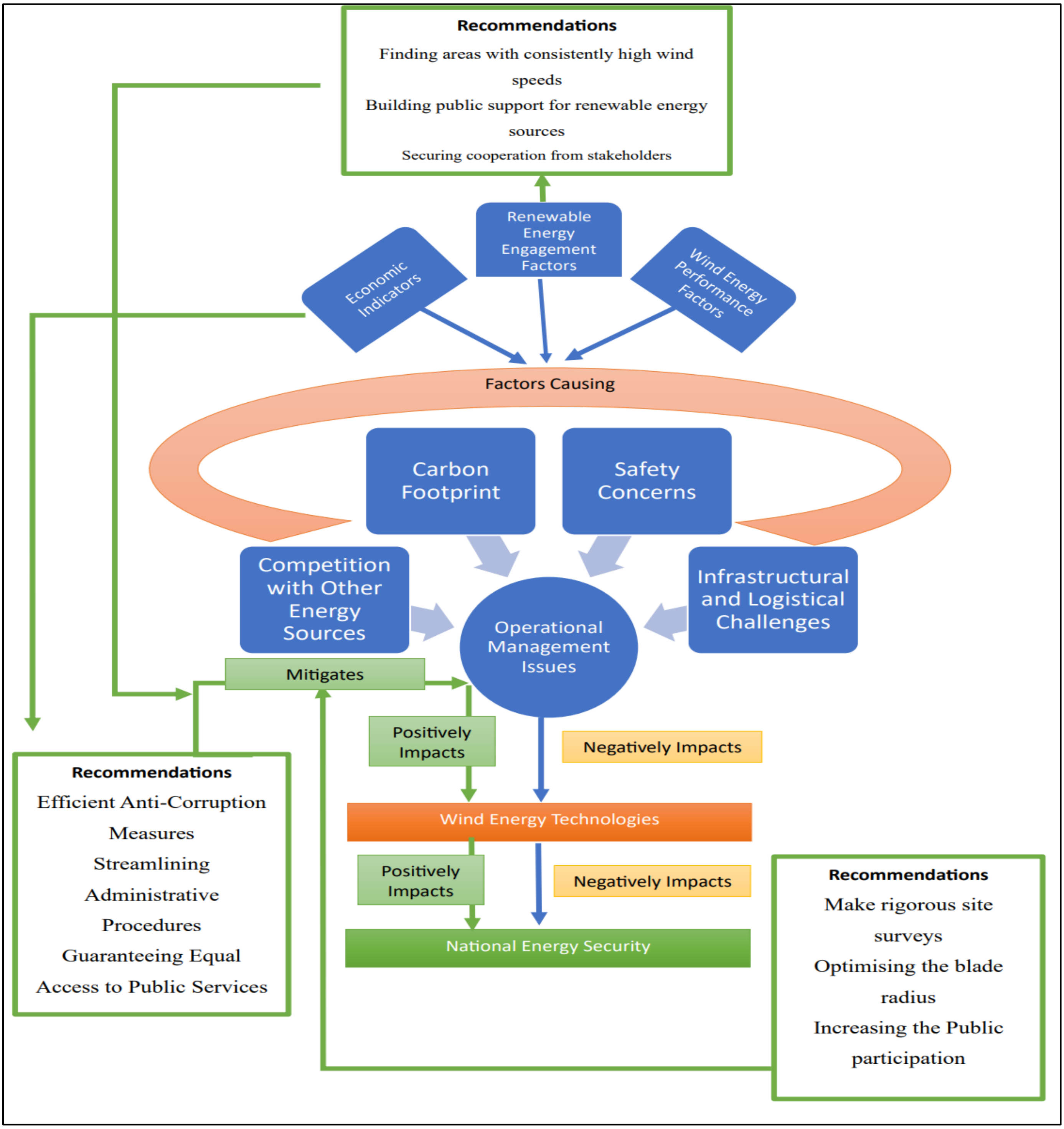

Fig 13: Optimization of Wind Energy Solutions for National Energy Security (Created by author)

Figure 13 shows the Optimization of wind energy solutions for national energy security sector, it is essential to prioritise good governance, support economic growth, attract investments, control inflation, actively participate in renewable energy initiatives, and optimise wind energy performance in order to achieve the goals and objectives of wind energy technology and improve national energy security. Additionally, this strategy must focus on encouraging open communication and investigating community ownership models for local advantages. Give improving governance a high priority for stability and transparency.

➢ *Justifications of Economic Indicators in the Developed Model*

- Economic Indicators such as Governments should prioritise accountability, openness, and a decrease in corruption in order to enhance governance. This indicator can be enhanced by putting in place efficient anti-corruption measures, streamlining administrative procedures, and guaranteeing equal access to public services.
- Governments should strive to streamline bureaucratic procedures and lower administrative barriers for citizens and companies. This can entail streamlining rules, digitising government services, and establishing precise compliance standards.
- The development of infrastructure, the encouragement of innovation and entrepreneurship, and the maintenance of a stable macroeconomic environment are all things that governments should do to boost economic growth. Long-term economic growth can also be facilitated by policies that assist in the development of skills and education.
- Governments can implement measures that foster a favourable investment climate, such as offering tax advantages, enhancing infrastructure, and providing legal protection for foreign investors, to draw in more FDI and control inflation. Central banks can also use strong monetary policies to restrain inflation.
- To effectively control inflation, central banks must implement prudent monetary policies, including timely adjustments to interest rates and the money supply. In addition, they must address supply-side issues like rising food and energy costs by implementing agricultural reforms and energy efficiency measures.

➢ *Justifications of Renewable Energy Engagement Factors in the Developed Model*

- Finding areas with consistently high wind speeds is necessary to increase the production of renewable energy from wind. To determine the ideal locations for wind energy projects, conduct detailed wind resource analyses. Invest in cutting-edge wind monitoring tools like LIDAR to increase the precision of wind speed forecasts. Collaborate with private businesses and meteorological organisations to collect thorough wind data.
- Building public support for renewable energy sources, such as wind energy, is essential for their effective adoption. Organise effective public awareness campaigns emphasising the advantages of renewable energy, such as the creation of jobs and a decrease in greenhouse gas emissions. To allay worries and doubts regarding wind energy projects, engage in community outreach and consultation. Offer incentives to encourage participation in renewable energy efforts and the sharing of the benefits, such as community-based renewable energy programmes.
- The success of renewable energy projects depends on securing cooperation from stakeholders, such as local governments and organisations. To include stakeholders in the project planning and decision-making processes, establish clear communication routes with them. To allay worries and lessen potential harm to stakeholders, do detailed impact evaluations. Develop supportive laws and rules for renewable energy projects in conjunction with local government, including expedited permitting procedures.

➢ *Justifications of Wind Energy Performance Parameters in the Developed Model*

- Optimising this parameter is critical since air density has a substantial impact on wind turbine performance. Make rigorous site surveys to find areas with the right air density for wind energy projects. To forecast changes in air density and deploy turbines most effectively, use meteorological data and modelling. Investigate high-altitude wind resources, where air density could prove more reliable and advantageous for energy generation.
- Optimising the blade radius is essential since the size of wind turbine blades has an impact on energy extraction. Spend money on research and development to create turbine blades that are longer and more effective while also taking material strength and structural integrity into account. Perform aerodynamic analyses to improve blade design, lower drag, and boost energy conversion effectiveness. When possible, extend the blades of existing turbines to improve their performance.
- The success and acceptance of wind energy projects are positively impacted by public participation. In order to include local communities in project planning and decision-making, open and transparent lines of communication must be established. To enlighten the public about wind energy's advantages and answer concerns, hold open forums, workshops, and informational sessions. To ensure that locals directly profit from wind energy projects through revenue sharing or lower energy prices, take into account community ownership or profit-sharing schemes.

D. Research Relevance

The study highlights complex issues in wind energy technology adoption and management, highlighting competition, carbon footprint, safety, and logistical difficulties. It emphasizes strategic planning, inter-disciplinary cooperation, and creative thinking for long-term growth.

A structured framework for optimising wind energy technology is also introduced by the research using the findings of the factor analysis. It offers policymakers, governments, and industry stakeholders' clear direction by providing reasons for economic indicators, factors influencing the engagement in renewable energy, and wind energy performance measures. For instance, the focus on reducing administrative procedures, encouraging public support for renewable energy sources, and optimising blade radius outlines concrete methods to increase the uptake and performance of wind energy. The research aims to increase wind energy uptake and performance, contributing to national energy security and sustainability.

E. Chapter Summary

This chapter presents a thorough study of the findings from factor analysis, with a major focus on the complex factors affecting the uptake of wind energy technology. In this context, important variables include things like air density, blade radius, and stakeholder acceptance.

- These elements have a moderate impact, according to an assessment using the Likert scale. In order to better understand how these elements interact and are important in the context of the adoption of wind energy, principal component analysis further simplifies them into three essential components.
- This chapter also addresses how these discoveries might be put into practice, highlighting the crucial role that wind energy plays in diversifying energy sources, decreasing dependency on fossil fuels, and boosting national energy security. Strategic planning and interdisciplinary collaboration are required to handle the difficulties associated with carbon footprints, safety concerns, and logistical obstacles.
- For policymakers and stakeholders, the chapter presents a well-organised framework for maximising the uptake of wind energy technologies. In general, these discoveries support the national promotion of reliable and secure energy systems.

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CHAPTER SIX
RECOMMENDATIONS

A. Introduction

Through this chapter the author provides the recommendations for mitigating the operational management issues in using the wind energy technologies for improving the national energy security. The author in this chapter also develops recommendations for the future research endeavours also.

B. Recommendations Based on the Findings of the Research for the Improving the National Energy Security

- **Financial Innovation and Low-Cost Funding-** It is imperative for the government to develop novel financial instruments and investment mechanisms that can provide the renewable energy industry the crucial low-cost capital it requires, along with extended repayment periods of 25 years (Thanthi, 2018). When considering wind power alone, an annual capacity of 8,000 MW requires project debt finance amounting to around Rs 40,000 crore. India should consider the implementation of regulations governing a Green Bond Market and the facilitation of the influx of affordable offshore funds, such as Pension Funds, into the renewable energy sector. Indian corporations often have high levels of debt, which may be attributed to factors such as project delays or economic downturns. The relaxation of sectoral and group exposure limits by the Reserve Bank of India (RBI) has the potential to significantly facilitate finance for renewable energy projects (Thanthi, 2018). The implementation of a 5 percent subsidy by the government for the use of domestically produced goods will effectively support and advance the Make in India campaign. The use of the National Clean Energy Fund and the exploration of offshore funds by IREDA may also be effectively utilised. In an alternative approach, we may draw insights from the financing system used in Brazil, which aims to promote local value addition via the utilisation of low-cost, long-term funding. The implementation of innovative financing strategies and the availability of low-cost capital will potentially bring about a transformative effect on the expansion of renewable energy sources in India (Thanthi, 2018).
- **Policy Predictability-** The ongoing shift in wind energy from the Feed-in-Tariff (FiT) system to a competitive bidding framework has provided momentum to the wind energy industry, which is projected to expand at an annual rate of around 10-14 GW (Thanthi, 2018). While this phenomenon has resulted in extended periods of market exposure for the investor, it has concurrently engendered transient fluctuations in market conditions. It is recommended that governments adhere to previously negotiated agreements and fulfil their non-solar Renewable Purchase Obligations (RPOs). In the context of solar energy, it is essential for governments to consistently allocate bankable power purchase agreements (PPAs) with specific capacity targets. Furthermore, the elimination of the Minimum Alternative Tax (MAT) for Renewable Energy sources until 2022, the enforcement of rigorous adherence to renewable purchasing commitments at the state level, and the provision of open access without any associated costs will also contribute significantly to the acceleration of this expansion (Thanthi, 2018).
- **The policy pertaining to offshore wind energy development**- India has an extensive coastline expanse of 7,600 km, hence presenting a substantial opportunity for the harnessing of offshore wind energy (Thanthi, 2018). The country has the ability to replicate the achievements shown in the domain of onshore wind energy within this offshore context. India should prioritise the development of a streamlined process for obtaining clearances and establishing a framework for implementing offshore wind projects. This would enable the country to effectively harness these resources and bring them to fruition in a timely manner.
- **Altering the Specifications-** The rotor diameter refers to the measurement of the circular span created by the blades of a wind turbine. At now, the typical rotor diameter of an onshore wind turbine is 120 metres. Nevertheless, it is projected that by the year 2035, the diameter is anticipated to expand to 174 metres. The use of wind turbines with bigger rotor diameters enables the coverage of a broader expanse, hence enhancing the potential to harness a greater amount of wind energy (Thanthi, 2018). Hub height refers to the vertical distance between the ground and the topmost point of a wind turbine structure. An increase in hub height results in more wind exposure for the turbine as a consequence of its elevated position. The average hub height of onshore wind turbines in 2019 was recorded at 89 metres. According to projections, by the year 2035, it is anticipated that this measure would see a significant rise to 130 metres, hence leading to a substantial enhancement in wind energy capacity (Thanthi, 2018).
- **Getting Smarter-** Modern wind turbines are equipped with advanced sensors and precise controls that continuously adjust the position of the blades. This optimisation process aims to maximise the use of wind energy while also providing valuable information to wind farm management. The orientation of each turbine blade is subject to constant adjustment. Intelligent controls increase the surface area of the blade in order to optimise wind collection. In the event of gusts reaching hazardous levels, it is possible to rotate the blades in order to reduce their vulnerability and mitigate the potential for harm. Advancements in meteorological prediction techniques are concurrently enhancing the energy generation capacity of wind farms. Enhancing the precision of wind predictions may result in a 10 percent increase in power dispatch, enabling the sale and integration of a greater amount of energy into the grid (Thanthi, 2018). This improvement is achieved by gaining a more comprehensive understanding of the intermittent characteristics of wind. In addition to their primary function, contemporary turbines are capable of offering supplementary services, sometimes referred to as "ancillary services," which include reactive power provision and frequency regulation. These tasks serve the purpose of enhancing the stability of the grid or local network to which a wind farm is interconnected, so successfully guaranteeing the uninterrupted operation of electrical lighting systems (Thanthi, 2018).

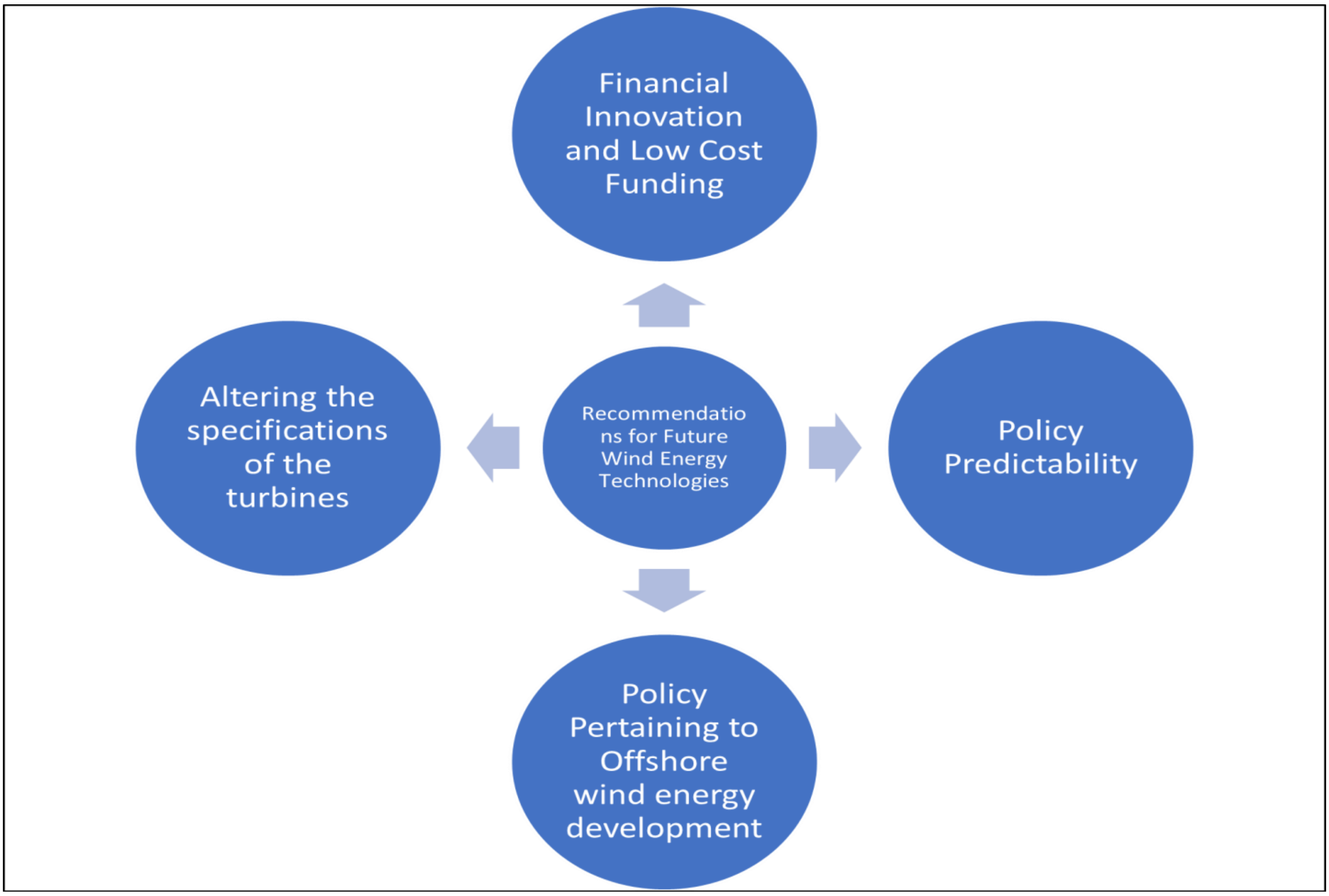

Fig 14: Recommendations Based on the Findings of the Research (Created By author).

Based on the findings of the research the author develops the recommendations mentioned above and on the figure 14 the following section describes the recommendations for the future research endeavours.

C. Recommendations for the Future Researchers

➢ *Based on the Research Process, the Author Develops the Following Recommendations for the Future Research Works:*

- The research can be used as a template for the future researchers to develop their research base for conducting further study on the wind energy technologies
- Future researchers can use the model developed in this research for working further on the field of wind energy.
- The researchers could use other analysis tools for the development of research findings other than the chi square test and the spearman correlation analysis.
- The researchers can expand their research base through the incorporation of more human samples and focussing on other geographical areas.

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CHAPTER SEVEN
CONCLUSIONS

A. Introduction

Through this section the author summarizes the findings of the research process in conjunction with the research objectives. The research findings can be summarized as follows:

B. Conclusions

The research aims to identify and evaluate the Operational Management Issues on the Wind Energy Technologies on National Energy Security. The objectives of the research have been achieved by the author as follows:

- The first objective of the research can be accomplished through the review of relevant literature. By conducting the literature review the author identified the uses of wind energy technologies on the national energy security.
- For the purpose of achieving the second objective of the research the author utilized the literature review and identified the major operational management issues in the usage of wind energy technologies for national energy security. The major operational management issues identified by the author includes:

✓ Competition with Other Energy Sources
✓ Carbon Footprint
✓ Safety Concerns
✓ Infrastructural and Logistical Challenges

- The third objective of the research was to identify the factors that affect the operational management of wind energy technologies. The following are the main factors identified from the literature review:

✓ Political Factors
✓ Economic Factors
✓ Mechanical Factors
✓ Psycho-social Factors

- Based on the factors identified from the literature review the author created a survey questionnaire and performed the survey by incorporating experts from the field of Energy management
- The adoption of wind energy is influenced by a multitude of variables, as shown by descriptive statistics. In addition to factors such as air density and blade radius, the significance of stakeholder acceptability has been identified. The findings of the Likert scale research indicate that the impact is characterised as modest.
- The user's text does not provide any information to rewrite in an academic manner.The principal component analysis (PCA) identifies and extracts three fundamental components. The Rotated Component Matrix is used to elucidate correlations and generate components pertaining to wind performance and renewable energy.
- For the purpose of accomplishing the fourth research objective the author performed a factor analysis and gathered 3 components out of the survey variables. The variables were selected based on their eigenvalues greater than 1.

➢ *The Components Gathered from the Factor Analysis are as Follows:*

- Economic Indicators
- Renewable Energy Engagement Factors
- Wind energy performance parameters

Based on the components gathered from the factor analysis the author developed a model for the effective adoption of wind energy technologies for improving the national energy security.

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APPENDIX

A. Survey Questionnaire

My current academic affiliation is with UWE Bristol, where I am enrolled as a master's degree candidate. I can be identified by the name of NAME. Currently, I am actively engaged in an academic endeavour that entails the execution of a comprehensive research project in order to meet the criteria for my master's thesis. The primary objective of this study is to identify and assess the operational management issues pertaining to wind energy technologies and their impact on national energy security.

- The objective of this survey is to collect relevant data to substantiate my scholarly inquiry.
- Rest assured that the data obtained from participants will be exclusively utilised for scientific research objectives, and stringent measures will be implemented to uphold confidentiality for all responses.

We would like to express our utmost gratitude for the time and commitment you have devoted to providing answers to the inquiries presented in this survey.

All* marked fields are mandatory.

Section A- Background Information

➢ *Consent for Participation*

I am ready to participate in the Survey	☐
I am not ready to participate in the Survey	☐

➢ *Gender (Mark Only One*)*

Female	Male
☒	☒

➢ *Profession (Mark only one*)*

Employees in the field of Renewable energy	☐
Renewable Energy Entrepreneurs	☐
Windmill Owners	☐
Wind technology Manufacturers	☐
Students in the Field of Energy management	☐
Research Scholars	☐

➢ *Are you Aware that Wind Energy can be Used as a Renewable Energy Source? (Mark only one*)*

Yes	No
☐	☐

➢ *Do you Think That Wind Energy is a Reliable Source of Energy? (Mark only one*)*

Yes	No
☒	☐

➢ *Are you aware about the National Energy Security? (Mark only one*)*

Yes	No
☒	☐

➢ *Do you think that the usage of renewable energy sources such as wind energy can improve the National Energy Security? (Mark only one*)*

Yes	No
☐	☐

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B. Section B- This Section Deals With The Impacts Of Operational Management Issues On Wind Energy Technologies.

➢ *How do you rate the impacts of the following operational management issues on the implementation of wind energy technologies? (**Mark only one checkbox for each factor) ***

Operational Management issues	Very Low Impact	Low Impact	Moderate Impact	High Impact	Very High Impact
Safety Concerns	☐	☐	☐	☐	☐
Carbon Footprint	☐	☐	☐	☐	☐
Competition with other Energy Sources	☐	☐	☐	☐	☐
Infrastructural and Logistics Challenges	☐	☐	☐	☐	☐

C. Section C- This Section Evaluates the Impact of Political Factors on the Operational Management Issues of Wind Energy Technologies.

➢ *Do you agree that the strict government policies regarding the usage of wind energy technologies impacts in the operational management of wind energy technologies? *(Mark only one)*

Definitely Would	1	☐
	2	☐
	3	☐
	4	☐
Definitely would not	5	☐

➢ *Do you Believe that there are Numerous Administrative Challenges in Implementing the Wind Energy Technologies? *(Mark Only One)*

Strongly believe	1	☐
	2	☐
	3	☐
	4	☐
Weakly believe	5	☐

D. Section D- This Section Outlines The Economic Factors That Causes The Operational Management Issues In The Implementation Of Wind Energy Technologies.

➢ *Do you believe that the economic growth can be facilitated through the implementation of wind energy technologies? *(Mark only one)*

Definitely Would	1	☐
	2	☐
	3	☐
	4	☐
Definitely would not	5	☐

➢ *How do you rate the impact of the Foreign Direct Investment on the operational management of wind energy technologies? *(Mark only one)*

Very High Impact	1	☐
	2	☐
	3	☐
	4	☐
Very low Impact	5	☐

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➢ *Do you believe that the Inflation is a primary economic factor that affects the use of renewable energy technologies? *(Mark only one)*

Definitely Would	1	☐
	2	☐
	3	☐
	4	☐
Definitely would not	5	☐

E. Section E- This Section Deals with the Mechanical Factors That Causes The Operational Management Of Wind Energy Technologies.

➢ *How do you rate the impacts of the following mechanical factors on the operational management of wind energy technologies? (Mark only one checkbox for each) **

Challenges	**Very Low Impact**	**Low Impact**	**Medium Impact**	**High Impact**	**Very High Impact**
Wind Speed	☐	☐	☐	☐	☐
Air Density	☐	☐	☐	☐	☐
Blade Radius	☐	☐	☐	☐	☐

F. Section F- This Section Deals With The Impacts Of Psycho-Social Factors On The Operational Management Issues Of Wind Energy Technologies.

➢ *Rate Your Opinion About The Impact Of Psycho-Social Factors On The Operational Management Of Wind Energy Technologies? (**Mark Only One Checkbox For Each)** **

Challenges	**Very Low Impact**	**Low Impact**	**Medium Impact**	**High Impact**	**Very High Impact**
Public Acceptance	☐	☐	☐	☐	☐
Citizen Engagement	☐	☐	☐	☐	☐
Stakeholder Acceptance	☐	☐	☐	☐	☐