

An Examination of Cloud Computing's Impact on Sustainable Development: Its Significance, Research, and Possible Difficulties

Dr. Ranjan Kumar Mondal

Assistant Professor, Department of CSE, Swami
Vivekananda University, Kolkata, WB

ranjankm@svu.ac.in

Abstract:

Sustainable development is an approach that considers both short- and long-term needs, such as economic and social justice, environmental preservation, and natural resources. A cloud computing environment is made available to users to facilitate flexible innovation, scalable capabilities, and scale economies. It includes analytics, software, networking, databases, storage, and servers. This study examines many cloud qualities that benefit sustainable development, including resource pooling, simple maintenance, favorable economic effects, and extensive network access. This research also looks at many aspects of modern cloud service providers that support sustainable growth, such as Microsoft Azure, Google Cloud, and Amazon Web Services (AWS). Finally, this study discusses possible issues with cloud sustainability, including lack of knowledge, hidden costs, security, and administration.

Keywords: cloud computing, sustainable development, economic, environmental, and social sustainability; cloud deployment methods; cloud characteristics; cloud service models;

I. OVERVIEW

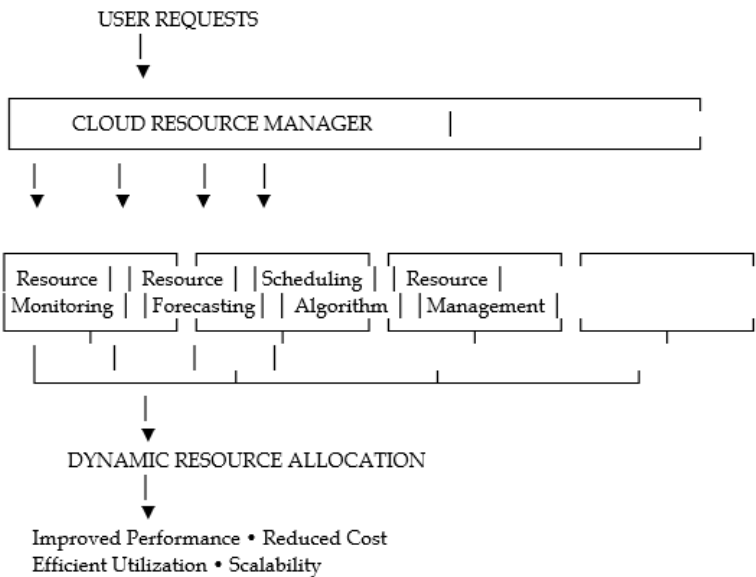
Sustainable development aims to meet current needs without endangering the ability of future generations to meet their own needs [1]. The world faces essential issues related to natural resources and ecosystems, including global

warming, freshwater scarcity, marine resource exploitation, deforestation, pollution, and the struggle to feed billions of people. Sustainability in the environmental context is the management and preservation of Earth's natural resources, biodiversity, climates, and atmosphere to ensure the well-being of current and future populations [2]. Cloud computing provides computing environments, such as servers, analytics, software, networking, databases, and storage, to facilitate scale economies, scalable capabilities, and quicker creative thinking.

Data are required to track and monitor the objectives to ensure the SDGs are reached by 2030. To close the existing information gap supporting the SDGs, a creative and effective technique of gathering and using data must be developed to lower the cost associated with traditional statistical approaches. One of the critical factors influencing innovation nowadays is a sustainable approach and environmental concerns. One of the most influential and environmentally friendly information and communication technologies is cloud computing, which saves businesses more than 200 billion euros and 59 million tons of carbon dioxide annually. These advantages may be attributed to the increasing popularity of on-demand service delivery, dynamic resource allocation, increased error detection, and greater flexibility. Because it is based on a community of cloud computing platforms, it reduces energy consumption and pollutants from traditional server and local application techniques while enabling up to 50% cost reductions.

This article investigates how cloud computing affects sustainable development and promotes innovation, performance, and social, environmental, and economic change. Additionally, the research examined the possible obstacles that cloud computing may pose to sustainable growth. The literature on cloud computing and sustainable development is reviewed in Section II. Cloud service models, such as Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS), are also covered in this area. The modes of cloud deployment—public, private, hybrid, and community—are also covered. This section

examines cloud properties that support sustainable growth, including broad network access, resource pooling, simple maintenance, and sound economic effect. The major cloud providers, such as Amazon Web Service, Google Cloud, and Microsoft Azure that support innovation, performance, and transformation in sustainable development are covered.



II. REVIEW OF LITERATURE:-

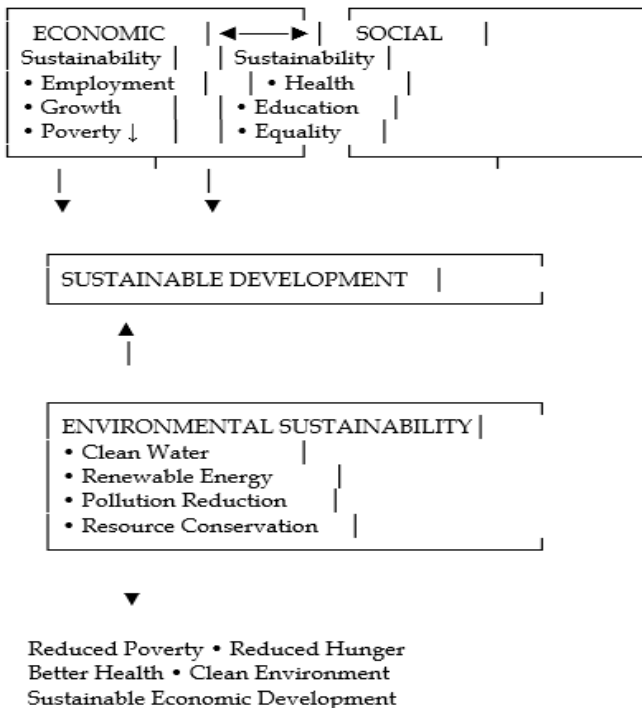
A. Long-Term, Sustainable Growth sustainable development aims to organize civilization in a way that will guarantee its continued existence. This means considering short- and long-term needs, such as natural riches, environmental preservation, or social and economic fairness. The United Nations established the Sustainable Development Goals, a collection of 17 global objectives, as a roadmap for building a more promising and sustainable future for all people [1]. The goal is to balance socio-political stability, economic viability, and ecological stability. By gradually changing how people generate and use innovations, sustainable development constantly inspires people to protect and enhance their assets.

Every country has to provide the necessities of labor, food, electricity, water, and sanitation. Everyone has a right to a safe, secure, and hygienic environment. Reducing unemployment, inequality, and pollution are easy ways to do this.

Among the four goals of sustainable development are:-

- Sustainable financial development ends poverty and hunger and promotes a healthy way of life.
- Protection of natural resources: Ensure that necessities like food, sanitation, and environmental sustainability are fully provided.

LONG-TERM SUSTAINABLE GROWTH



III. Social progress and equity:

Eliminate all forms of prejudice, especially sexual discrimination. Provide opportunities for fair education and fulfilling work to the next generation. Build communities and areas that produce and consume sustainably, resulting in organizational flexibility and strong networks.

Environmental protection includes preventing climate change, preserving agricultural and marine biodiversity, and defending the ecosystem.

The primary international framework for international cooperation in the twenty-first century is the 2030 Agenda for Sustainable Development and its Sustainable Development Goals. The Sustainable Development Goals (SDGs), sometimes called the Global Goals, were adopted by the United Nations in 2015 as a worldwide response to the need to end poverty, protect the environment, and ensure that all nations have peace and stability by 2030. The seventeen Sustainable Development Goals (SDGs) are interrelated because they acknowledge that decisions made in one area will affect outcomes in other places and that social, economic, and environmental sustainability must be managed as a consequence of growth.

Figure 1. The Interconnection Between Environmental, Social, and Economic Sustainability



Figure. 1. The connection between environmental, social, and economic sustainability

Development, administration, intellectual pursuits, and humanitarian aid have all shown great interest in sustainable development. Many public and commercial organizations have accepted it as a practical conceptual framework. Sustainable development requires multi-leveled, integrated efforts considering social, environmental, and economic concerns rather than isolated activity. Detangling the complex relationships between the goals and the objectives will be essential to implementing the SDGs effectively.

Cloud -Based Software

Thanks to cloud computing, consumer devices may access external virtual hosts, databases, and systems online to acquire information and cloud services. High-quality information is necessary to monitor progress toward the Sustainable Development Goals (SDGs), evaluate the effectiveness of legislation, and advise executive management and financial choices. Big data and cloud-based infrastructure have given rise to creative concepts for data collecting that affect both the execution of the activities and the use of reliable data collection methods. To provide insights, data are needed to examine the relationships between several significant topics and social and economic specifics. In addition to national statistical data, there is a need for spatial data that can be split down for vulnerable populations.

The research demonstrates that cloud-based solutions that combine crowdsourcing with open-access EO data sources provide valuable choices for monitoring and following Sustainable Development Goals, particularly for low-income countries. The authors explained that cloud computing may be built for essential topics to monitor, assess, and analyze the advancement of the SDGs, particularly for quick inspections, and to provide real-time support for decision-making. For example, Google has developed a GEE cloud architecture that significantly improves massive data handling and processing capabilities for environmental monitoring. Many businesses are concentrating on cutting carbon emissions to create a long-term plan for environmentally friendly, sustainable growth. Cloud computing offers several benefits for this outcome. The organization shares its equipment to enhance

use rather than having each business on its own. Furthermore, servers are kept in climate-controlled spaces with continuous temperature and humidity monitoring.

The cloud offers several financial benefits, such as cost reductions and increased productivity at work. Moving from on-premises systems to the cloud has many advantages, such as reduced waste, operational expenditures being replaced by capital investments, and flexibility without adding more gear, which lowers hardware costs. Off-site hardware lowers power supply expenses, frees up workspace, and saves money on purchases. When cloud devices are retired, these benefits reduce energy use and ecological harm. Cloud computing lowers electricity costs while simultaneously cutting energy use. Cloud computing dramatically increases economic speed by employing network-connected distant systems instead of local ones. It also reduces operational expenses and provides improved performance and flexibility for business expansion. A virtual conversation framework provided by the cloud may reduce costs and save up to 50% of the time compared to in-person talks [1].

Additionally, employing cloud services may result in considerable savings on staff and service costs. Because cloud computing improves employee productivity and directly reduces labor costs, it may be highly cost-effective for enterprises. Furthermore, the research from [2] also found that companies may move their mission-critical legacy systems to the cloud, a workable alternative environment with better options. According to the research [3], cloud-based solutions are dependable and flexible to help and improve small to medium enterprises (SMEs) for enhanced performance. Additionally, the research of [4] explored how cloud computing and big data can help businesses make better decisions, understand customers, and manage operations.

Additionally, cloud computing may allow educational districts to save money on maintenance, electricity, and infrastructure. Online resource versions are now available to schools, saving money and ensuring students learn from the most recent resources. Cloud computing may lower the costs related to photocopying and printing. Integrating cloud

computing into educational systems will ultimately help institutions realize their goals and guarantee the success of their students. For instance, teachers may save all assignments and class materials in the cloud. Users may link these to other educators and decision-makers over the cloud to receive their feedback. This makes it simpler for instructors to adapt their ideas and enhances class preparation year after year. The data will be stored on the cloud, saving the need to rebuild it if an instructor's equipment malfunctions. Additionally, by using the cloud, administrators, and schools can easily arrange and share important documents and policies with every employee.

Models of Cloud Services

Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS) are the three main categories into which cloud services may be separated. These cloud services are helpful in terms of economic, social, and ecological growth. Infrastructure as a Service (IaaS) is an online virtual computer service provider. Under the Infrastructure-as-a-Service (IaaS) model, cloud hosting manages IT assets, such as servers, storage, and networking devices. It provides them to customer businesses via virtual servers available over the internet. Web applications may be distributed as a service using the SaaS approach. By only accessing software over an online platform instead of installing and maintaining it, users may escape the hassles associated with complex program administration. PaaS is a cloud technology strategy in which hardware and software resources are distributed online to customers by a third-party provider. Building programs usually require these resources. The supplier's internal network hosts both the hardware and software. Thus, PaaS removes the need for developers to download their software and hardware to create or run a contemporary service.

IaaS may make operations faster, more accessible, flexible, and affordable regarding sustainable economic growth. IaaS helps to promote sustainable economic development by giving companies the flexibility to choose the services and solutions they need. While the cloud provider manages the infrastructure, businesses can concentrate on downloading, installing, and managing apps and safeguarding their data. It

is also cost-effective as companies only pay for the computing, storage, and networking resources, and IaaS costs are easily anticipated and budgeted for. Additionally, SaaS promotes corporate expansion, which ultimately contributes to economic sustainability. SaaS options provide a unified opportunity for straightforward, distinctive customer addition, feature flexibility, and the newest tailored business solution. SaaS services may significantly reduce operating and maintenance costs, allowing management to finance investments in other areas while maintaining a reliable and secure system. PaaS reduces business costs by providing software foundation facilities. There is no wastage of beneficial money since customers only pay for the resources they utilize.

Energy management is one of the most essential environmental control methods for ecologically sustainable growth. Instead of manually gathering data and entering it into an Excel spreadsheet, more firms are embracing Software as a Service (SaaS) to monitor and manage energy use. One SaaS tool for energy management, called Energy Watch, integrates data insights inside Watch wire to work as a productive partner for risk analysis and energy resources. They work in conjunction with enterprises to determine the optimal length of agreement terms for energy procurement, power supply services, and terms of agreement contracts. SaaS applies to oil and gas management in addition to energy management. Demands on oil and gas companies to demonstrate their efficacious ecological management and sustainability activities are growing. The SaaS system, which shows real-time oil and gas control activities, has dramatically simplified the initial certification process and provided a strong foundation for ongoing safety and risk assessment. It offers an advanced, cost-effective single platform to reduce complexity, boost output, and encourage sound risk management across sustainability, ecological governance, and standard control.

SaaS solutions for legal practice management (LPM) use law practice management software, which contributes to social sustainability. Legal firms use SaaS to help with task administration, accounting, networking, documenting, task delegation, billing, and advertising. Innovation has changed

the legal profession in the same way that it has changed the business sector. Legal practices may save and find client personal information with the help of Law Practice Management Software. It provides the company with a single connection database. It gives a ready store for searches and aids in the upkeep of articles per connection. Generally, the program facilitates the recording of invoices, which may help with managing reports, debtors, costs, timesheets, and customer issues, among other things. Regularly, transactional, or conditional makes monitoring taxable times easier.

Additionally, IaaS is crucial to education under socially sustainable growth. The educational sector has already seen the flexibility of the cloud's operations. They might now use the clouds to support the recently emerging trend of disjointed processes. IT executives and administrators need to understand that Infrastructure as a Service (IaaS) is a valuable tool enabling educators and students to access innovative materials quickly and at a reasonable cost. It is not just a band-aid fix that proved handy during the COVID-19 pandemic. IaaS is a crucial enabler of technological advancements supporting academic teaching and virtual education programs that will allow advanced learning in the next few years. Institutions that integrate Infrastructure as a Service (IaaS) into their computing portfolio will be better prepared to manage staff and student technology needs in the future.

Models for Cloud Deployment

The goal and nature of the cloud, as well as the particular kinds of cloud infrastructure rights of accessibility, scalability, and governance, are all described in the cloud deployment model. Four primary categories of approaches for cloud deployment consist of communal, hybrid, private, and public clouds. The general public may access the public cloud via the internet. The cloud services company controls the technology in this public cloud, not the user. It is a hosting service that makes it simple for users to connect to networks and apps.

Public cloud providers like AWS and Azure have committed to using entirely renewable energy by 2025, playing a part

in ecologically sustainable development. Meanwhile, Google Cloud Platform has declared itself carbon-neutral and plans to use only carbon-free energy by 2030. Moreover, AWS, Azure, and GCP have advanced beyond internal projects like environmentally friendly supply chains, eco-friendly data centers, and advancements in renewable energy. They've all introduced cloud-native technologies, allowing customers to determine their carbon emissions quickly. For instance, using the GCP Carbon Footprint tool, users may track and assess the carbon pollution caused by personal cloud use and the carbon emissions of inactive public clouds.

The phrase “private cloud” describes a computer environment in which every piece of hardware and software is exclusively assigned to and accessible by a single client. Most choose the private cloud over the public cloud because it makes it easier for enterprises to comply with regulatory responsibilities. Private cloud deployments focus on sustainable economics as an alternative to public implementations. Big enterprises are finding the private cloud an increasingly appealing alternative because it offers features similar to public technology inside what they perceive to be a more stable financial structure. Connecting to a cloud network speeds up company data interchange, making joint decision-making simpler and more efficient, ultimately boosting productivity.

A hybrid cloud is an integrated computing, storage, and services platform comprising public cloud services, on-premises infrastructure, and private cloud services. Businesses may use on-premises equipment and data center services while expanding by using the hybrid cloud. In a time when the global community is primarily concerned with sustainable development, hybrid cloud technology gives businesses the power to direct growth and improve their sustainability legally. Additionally, a hybrid cloud platform allows companies to use the services they need when they need them. Hybrid clouds mix limited on-premises system maintenance with infinite public cloud services to promote sustainable growth.

Community cloud computing is a term used to describe a collaborative cloud computing resource platform for a limited

number of enterprises or workers. Another significant factor in socially sustainable development is community clouds. Community clouds are widely used for patient information communication between labs and healthcare institutions. They could use a HIPAA-compliant community cloud to do this without any problems. Pharmaceutical companies who trade data worldwide should also use it. For instance, the worldwide cooperative clinical investigation of the COVID-19 pandemic is presently being made more convenient by the community cloud's deployment. In addition, the community cloud allows instructors and students to share instructional materials to promote cooperative research. This will enable students to get the most recent and up-to-date instructional knowledge.

Features of the Cloud That Encourage Sustainable Development

1) Simple Upkeep

Servers are easily maintained, and there are never any significant disruptions. Services supported by cloud computing undergo several changes regularly to optimize their whole potential. Hardware upgrades are more practical and perform better than previous iterations. Because it saves time and money on maintenance, it is advantageous for sustainable development. One of the characteristics crucial to sustained growth, particularly in the commercial sphere, is the ease of cloud maintenance. Using a cloud-based management system lowers the cost of upgrades. Effective maintenance organizations must often accomplish more with less to reduce service costs. Due to reduced initial costs, this may be a highly tempting option that offers small businesses additional economic opportunities.

2) Advantageous Economic Effect

This particular cloud function helps reduce the IT expenditures of sustainable development organizations. When using cloud computing, the user is responsible for paying the administrator back for the capacity used. There aren't any additional expenses or hidden fees to pay. Some rooms are usually provided for free since the management

is thrifty. Additionally, this characteristic is essential to long-term economic growth. It also enables the IT department to produce more innovative and practical goods. IT inventions increase with business innovation, which creates jobs, and business development increases with more profit. Depending on its Economic Impact Model (EIM), IDC projects that Salesforce customers worldwide might expect a net revenue increase of \$375 billion between 2019 and 2024, with 53 billion coming from Western Europe.

3) Pooling of Resources

A hosting firm may allocate resources among many clients via resource pooling, providing customized features according to their requirements. It is a multi-client technique that may be used for computing, communication, and information storage, among other things. The client's experience is unaffected by the real-time resource allocation management technique [45]. This characteristic is crucial for sustainable growth. For instance, it may support socially sustainable development in the education sector by facilitating more effective lecturer-student sharing of course materials. It allows educators to share instructional materials quickly, administrators to communicate with one other and save money on file storage, and students to do assignments from any location with internet access, all of which contribute to an increase in the standard of education.

4) Broad Network Connection

The consumer may upload data to the cloud and see cloud data from any place with only a device and an internet connection. These features are accessible throughout the form and may be accessible via cloud computing support. Extensive network connectivity promotes paperless practices, which ultimately enhances environmentally friendly development. One advantage of cloud storage is that data may be retrieved anytime and anywhere. Another significant benefit is that data is not lost, unlike what sometimes happens to hard drives in data centers. The extensive network access architecture seeks to utilize less energy while providing clients with efficient services.

III. COMMON CLOUD PROVIDER ASPECTS THAT ASSIST IN ECONOMIC DEVELOPMENT

A. AWS, or Amazon Web Services

One of the critical components of AWS that supports sustainable growth is resource pooling. AWS's infrastructure resources are collected in several data centers worldwide and are distributed according to demand. As we go forward with our plan to run our company entirely on renewable energy by 2025, AWS is committed to sustainability and ongoing development throughout our global network. AWS is committed to helping Amazon achieve carbon neutrality by 2040. Customers may develop sustainability services by collecting, analyzing, and managing sustainability data using AWS services like waste reduction, resource efficiency, and monitoring emissions. AWS provides the broadest and most complete range of capabilities in computing, data analytics, the Internet of Things, machine learning, and artificial intelligence (AI) to assist the business in meeting its sustainability goals. AWS provides the expertise and resources needed for companies of all sizes and sectors to design and implement solutions that support their strategic goals.

In addition, one of the critical components of AWS in sustainable growth is broad network connectivity. The Amazon Sustainability Data Initiative (ASDI), one of the AWS products, may be used to illustrate this characteristic. To accelerate sustainable investment and innovation, ASDI works to lower the cost and duration of obtaining and assessing large datasets on sustainable development. The sophisticated technology, tools, and information needed by researchers and entrepreneurs to promote sustainability are made available by ASDI. Additionally, the AWS Customer Carbon Footprint Tool's functionality, which measures and reports emissions, also helps to provide an overview of carbon emissions. The Greenhouse Gas (GHG) Protocol standards should be followed when utilizing straightforward data visualizations to report pollution from AWS use. As Amazon approaches operating on sustainable electricity, users may also use it to plan and forecast how pollution will change.

B. Google Cloud

One of Google Cloud's products, the Carbon Sense suite, is a crucial component that supports measured and reported sustainable growth. It helps users take action to reduce their carbon footprint and accurately report the greenhouse gas emissions associated with their usage of Google Cloud. With the Carbon Sense package, users may take action towards a better environment by combining features from many Google Cloud products, including Carbon Footprint and Active Assist. By offering scalable services, Google Cloud also offers quick elasticity and scalability. For instance, it helps users of Google Maps make healthier choices. Google Maps lets users choose the route with the least fuel when traveling. This might save over a million metric tons of carbon emissions yearly, equivalent to removing over 200,000 cars off the road.

C. Microsoft Cloud

This cloud solution leverages the depth and breadth of the whole Microsoft cloud to help organizations take control of their environmentally friendly initiatives. It gives enterprises a collection of comprehensive, integrated, and algorithmic information and insight to expedite each stage of their sustainable journey. One of the critical characteristics of Microsoft Azure is flexibility. Users will be able to track their progress in reducing emissions and pinpoint specific sources of pollution. For instance, if an HVAC system is not meeting its designated decarbonization target, managers may be tasked with meeting current system requirements. Using the Vattenfall 24/7 Matching system, Microsoft was the first hyper-scale cloud hosting provider to assess hourly power usage and renewable power matching in a commercial offering. The solution to allow fossil-free existence for generations was developed with the help of Microsoft Azure technologies, including Azure IoT Central and Microsoft Power BI. Businesses may assess the environmental impact of renewable power sources and determine if their commitment to exclusively renewable energy covers every hour of consumption. The best people to explain the hourly need for renewable energy and help with production enhancement to meet demand are energy providers.

IV.POSSIBLE TROUBLES

Because cloud computing provides many benefits for businesses of all kinds, it has become increasingly popular in sustainable development. However, cloud computing has several possible drawbacks for sustainable growth. Security threats are the primary concern when using cloud computing. Sensitive and vital data is stored on cloud servers. Even if the hosting provider promises data integrity, the user is still responsible for user identity and permission, access control, encryption keys, and security mechanisms. Customer trust is eroded by identity theft, data breaches, cyberattacks, and other possible risks associated with the cloud. Income loss and damage to one's reputation and position might arise from this. Furthermore, using cloud computing requires sending and receiving enormous amounts of data rapidly, which increases the risk of security breaches.

Furthermore, even though almost all cloud service providers use a "Pay as you Go" model, which reduces the overall cost of the services used, there are times when a business using cloud computing may incur high costs. When assets are not optimized—for instance, when systems are not used to their full potential—the hidden costs rise. The overall cost goes up if there are unplanned spikes in use or less application monitoring. The underutilization of resources is one of the other main reasons for price increases. The cost will increase without using the resources if the user activates cloud computing and forgets to turn it off. At some point, this affects sustainable development.

Moreover, management is one of the difficulties that might affect sustainable growth. With more options, businesses today depend on many cloud services instead of just one. Most of these companies use several clouds and hybrid cloud solutions. This is sometimes difficult to execute and a hindrance to maintenance management. The process often becomes quite complex for the IT personnel because of the differences between different clouds.

Because cloud computing uses real-time resource allocation, it can handle vast volumes of data flowing to and from computers. This is only possible in the presence of a high-speed network. Even if these tools and data are sent across a network, they might still be vulnerable when insufficient bandwidth or unplanned interruptions exist. Businesses still need to ensure that there are no network outages and that the internet speed is adequate, even if they can lower the equipment cost. For smaller enterprises, maintaining network bandwidth, which comes at a high price, is thus a significant issue.

Lastly, a lack of knowledge about cloud computing affects sustainable growth. Working with it is sometimes lengthy because of the cloud's intricacy and high need for study. Proficiency and in-depth topic knowledge are required. Even if the sector is complete with experts, they must constantly improve their abilities. The cloud computing industry has a massive imbalance between supply and demand, which drives up wages. There are plenty of available jobs, but there aren't enough skilled cloud engineers, developers, and specialists. Therefore, upskilling is required so that these workers can actively understand, manage, and create cloud-based systems with the least amount of downtime and maximum reliability [58].

V. SUMMARY

In conclusion, a thorough discussion of cloud services, cloud deployment models, cloud features, and cloud providers' role in promoting sustainable development that enhances social, economic, and environmental progress was held. In addition, the administration, security, and privacy issues that may arise while using cloud computing for sustainable development have also been examined. Sustainability promotes human and community welfare, a more equal distribution of money, and the health and biodiversity of the environment. It is advised that to avoid identity theft, data breaches, and other possible risks, cloud computing security and privacy management be strengthened in future projects. Implementing a more flexible cost-counting method and controlling hidden expenditures

are also necessary for cloud adoption. Furthermore, additional study is required to enhance cloud management when organizations or businesses use multiple cloud platforms. It will also be essential to continually advance cloud understanding to create cloud-based systems with fewer faults and more dependability.

RECOGNITION

The University of Bahrain gave the authors of this research the chance to present it on the IEEE platform, for which they are grateful. Asia Pacific University of Technology & Innovation (APU) funded this study.