
Impacts, Challenges and Opportunities of Cloud Computing in Department of Works and Highways

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Abstract: The concept of cloud computing has been around since 1960 when J. C. R Licklider observed that users can share multiple computer resources remotely at any one time. This idea became reality when Microsoft in 2008 introduced its first ever cloud platform Azure which enabled users to share and access information such as videos, music, links and files. The Papua New Guinea National Department of Works and Highways (DOWH) embraces this digital technology by adapting the cloud-based Asset Work Manager (AWM) system which stores and manages road data. The system houses analytical tools such as RAMS/BAMS, GIS and HDM4 where the road data collected on site including project reports is uploaded onto the cloud server and analyzed to produce reports and patterns to guide decision making in road investments. With the aid of the cloud platform, road network planning has improved significantly from planning and programming of capital and maintenance works to implementation, monitoring and reporting. Like any other digital technological inventions, the cloud technology has its own challenges from a product perspective as well as user perception such as lack of expertise within DOWH to manage it, data security concerns, inefficient internet accessibility to all 22 provincial establishments, budget constraints, environmental factors and workforce adaptation. These challenges can be solved through creative thinking, capacity development, collaboration with cloud service providers such as PNG DataCo, improve internet accessibility and open dialogue with all stakeholders. The use of cloud and other digital technologies is here to stay with further developments and advancements expected in the future, therefore the department remains receptive to the changes and will use the technologies to its advantage while at the same time managing the challenges.

Keywords: Asset Work Manager (AWM), Bridge Asset Management System (BAMS), Department of Works and Highways (DOWH), Highway Development Module (HDM4), Road Asset Management System (RAMS).

1. INTRODUCTION

The overall Papua New Guinea Road Network is a system of roads and bridges that connects the four regions (Highlands, Southern, Northern & New Guinea Islands) and twenty-two provinces of the country. The existing network has a total length of about 30,000km of which 8,830.30km are national roads and 22,000km are provincial and district roads or in other description referred to as sub-national roads. These roads carry the majority of the passenger and freight traffic in the country and are vital for social and economic development. The Papua New Guinea Department of Works and Highways (DOWH) is in charge of the national road network in ensuring its serviceability, safety and sustainability while the Provincial and District Governments take carriage of the sub-national roads. Each year subject to funding availability, the department engineers from the Asset Management Branch in collaboration with the provincial engineers from the DOWH provincial establishments undertake road data collection exercises where information such as road asset inventory, road condition (IRI), traffic volume, safety, climate vulnerability, bridge condition and others such

as project reports are collected and uploaded onto the department's road management system called the Asset and Work Manager System (AWM).

This system is able to analyze the data using analytical software such as Highway Development Management Module 4 (HDM4) and produce results that are used to guide decision making in road development and maintenance investments. Over the years, the department has manually collected road data through the use of pen and paper till more recently laptops and gadgets like tablets have been used. These data are taken back to the office and analyzed which is a painstaking process to come up with the results. Storage of these information are usually kept in the on-premise servers or hard drives by individuals on excel files formats or printed hard copies. Main challenges and risks associated with this practice includes data security issues, time consumption, cost, manpower constraints and access to information in real time to influence decision making.

To address these issues and further improve road network planning, the Department of Works and Highways opted for the Asset and Work Manager System. The AWM system is cloud based, uses field-based applications for data collection, has GIS function to produce maps and ultimately serves as a one single source of truth system. As opposed to past scenario, access to information is real time as it is cloud based plus data is no longer required to be manually recorded as the field-based application allow data to be collected on site using tablets or android phones and uploaded instantly. The analytical function is also built into the AWM system, thus ensuring network planning decisions such as development of maintenance and capital budgets are evidenced based. The cloud technology has also enabled real time visibility of road asset inventory including information about the various road improvement and development activities on the network. Other software or applications can be seamlessly integrated or interfaced with the cloud-based road management system, thus increasing efficiency and resourcefulness. Importantly, standalone and outdated systems can be easily hacked, and manipulated by hackers who can steal valuable data from the inventory. With this cloud platform, there exist several layers of data security and safety, thus the road data is secured and reliable.

Road network planning in the Department will no longer be the same. With the introduction of cloud platform, we will monitor the performance of our roads and in the process develop long-term maintenance and capital works program to ensure optimal performance of the national road network whereby it stimulates socio-economic development.

Cloud computing is a technology that uses the internet to provide on-demand access to various IT resources, including servers, storage, and applications. It allows data and programs to be stored and accessed over the internet rather than on a local hard drive. This technology is beneficial because it reduces costs, provides easier access, decreases management expenses, and offers higher reliability. Examples of cloud services include Google Drive, Apple iCloud, Amazon Cloud Drive, Microsoft One Drive, and Oracle Cloud. Cloud computing is based on the concept of "Everything-as-a-Service" (XaaS), which includes Software-as-a-Service (SaaS), Platform-as-a-Service (PaaS), and Infrastructure-as-a-Service (IaaS) (Soni, 2025). Cloud computing is changing the way people handle tech resources these days, no more waiting around for IT experts to set everything up. Instead, users jump straight in and grab the computing power they need, right when they need it. This self-serve model means companies can adjust their resources on the fly scaling up or down almost like turning a dial based on real time demand. Cloud storage has changed the way we handle data in ways that you might not expect. Organizations now lean on distributed, remote servers to hoard huge amounts of information, leaving behind the constraints of physical hardware often a game changer when data expands faster than ever. Companies can shift resources around much more nimbly, boosting their return on investment. Plus, the broad set of analytics and management tools offered by cloud providers gives businesses insights that weren't that easy to come by before (Seal, 2025).

An industry that is impacted by cloud technology is the road sector. Cloud technology plays an important role in terms planning through to actual construction and sustainability of the infrastructure. Road transportation infrastructure assets are not only expensive to construct but also costly to manage, to satisfactorily meet public anticipation. Management of road asset infrastructure facilities is challenging particularly in developing countries because of the low level of industrialisation. An industrial revolution provides reasonable ways of managing existing assets in a way that provides maximum benefit to the public taking into consideration limited financial resources (Estache, 2000). To store and manage road asset data, a Road Asset Management System (RAMS) is required. A Road Asset Management System is a strategic and systematic process of maintaining, upgrading, and operating road assets effectively. Asset management uses information to look at the whole road network rather than individual schemes. It is about collecting physical inventory and managing current conditions based on

strategic goals and sound investments (Patil, 2019). Road data such as road inventory, pavement, structures, traffic, road safety to name a few are critical data input that are normally uploaded, stored and managed in the AWM which is then able to guide decision making in terms of road investments by providing network information, assist with road development planning, develop works programming and overall manage the life cycle of the roads.

In the “Pavement Maintenance Management System: A Review”, (Sarsam, 2016) of the University of Baghdad explains the two types of road maintenance management system, the first being the information system, which collects, organizes and stores data as network information and the second type which is the decision-support systems, which comprises applications modules to process the data and provide the information on which decisions can be based, and ultimately, implemented. For these systems to work effectively and efficiently, there must be a database where road data such as condition data, traffic data, safety and others are stored. In the Department of Works and Highways, the Asset and Work Manager is ultimately the road management system that stores and manages road data. This system is hosted with on premise servers which are managed by our ITC team. Over the years, it has become increasingly costly to sustain the ITC infrastructure coupled with manpower constraints, skills gaps, data security concern, poor internet accessibility, absence of road planning software and difficulty to access the data seamlessly. It is for these reasons that DOWH has opted to develop a road management system that is cloud based. By adapting cloud computing, we anticipate delivery of computing resources, such as servers, storage, and software, over the internet, rather than storing or processing them on local devices. This will allow our users to access these resources on demand, as needed, without needing to manage the physical infrastructure. Figure 1 below illustrates the Pavement Maintenance and Management system framework which articulates multiple road data streams which can be managed efficiently with cloud system.

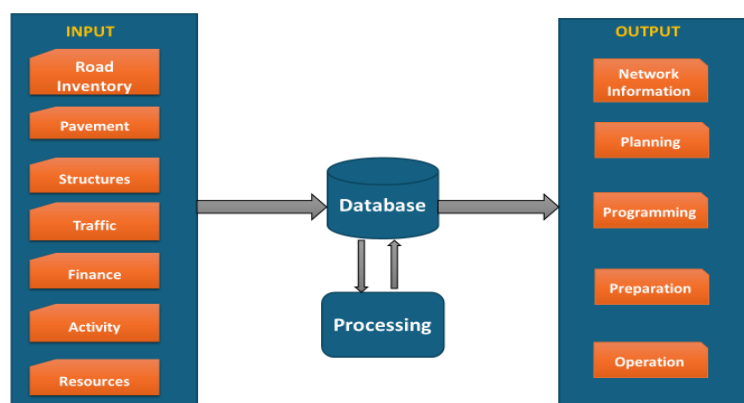


Figure 1. Basics and Concepts of Pavement Maintenance Management System (Sarsam, 2016). Modified by Solomon Pela (2025)

A cloud-based inventory and asset management system will empower the Department of Works and Highways to track and monitor its road assets, inventory status, and logistics in real-time, and get accurate business insights to make smart business decisions. Traditionally, the department performed this task manually, with pen and paper, or spreadsheets which has proven to be time consuming, costly and most times the data vulnerable to security threats such as manipulation of data. Ultimately, the road data must be analyzed to guide decision making in road investments and with the introduction of cloud computing, this is made possible and efficient. Cloud-based asset and inventory management systems can also have data analytics software, and data monitoring tools, which combined with real-time insights can give unprecedented control and transparency over the operations. Analytics can be effectively used to find the trends, and the insights related to demand and supply, and this translates to powerful business intelligence for optimizing all aspects of your operations (Sinha, 2022).

The objectives of this case study are to discuss the impact of cloud computing in the Department of Works and Highways in terms of road asset management, its challenges and opportunities. The study will also

give an overview of the Department’s current road management system and the thinking behind adapting a cloud-based system compared to the previous system which relied on servers kept on premise as well as the National Government’s position on cloud computing in PNG.

2. CLOUD COMPUTING IN PAPUA NEW GUINEA

The use of Information Communication Technology and Digital Technology started since 1990s. In Papua New Guinea, both the private sector and government organizations are using ICT and DT platforms such as cloud computing, AI and other technologies to enhance their strategic business objectives. In fact, organizations who build their planning and implementation models around ICT and DT seem to thrive and remain relevant where competition is high especially for businesses as well as effective service delivery for service-oriented organizations like government organizations. Digital government is the use of ICT to improve the efficiency and effectiveness of public sector operation and service delivery; or alternatively, the use by governments of ICTs to transform relations with citizens, businesses, and within government. Digital Government promotes and improves stakeholder contributions to development, as well as deepens the governance process (DICT, 2020).

The National Government of PNG (GoPNG) Digital Transformation Policy provides guidance and direction to PNG government departments and agencies on using the Government Cloud Infrastructure. It aims for efficient, secure, and sustainable cloud service consumption. The Department of Information Communication and Technology (DICT) is mandated to coordinate cloud services, data exchange, and shared services. The DICT is establishing a cloud platform for national and provincial government departments, including the DOWH. The "Cloud First" approach will help departments access current and emerging technologies to digitize their operations.

2.1 The Asset and Work Manager

The Asset and Work Manager is a cloud based world-class digital asset and work management solution that connects stakeholders in one seamless, single source of truth solution. It is a geospatial, real-time system supporting data accuracy and validation, making it possible to manage and maintain any asset class and type, in any location, at any time (thinkproject, 2025).

The system was introduced to the Department in 2022 and is currently in its second phase of development with 3 years remaining before the program becomes fully functional. At the conclusion of its development, the system is envisaged to perform the following key tasks; Systems Management, Network Management, Asset Management, Forward Works Programme Management, Pavement Management, Road Structures Management, Works Management, Emergency Management, Drainage Management, Safety Management and Asset Valuation. Performing these tasks require massive amount of data to be first uploaded into the system with the inbuilt analytical tools like HDM4 and GIS producing the expected results. This can only be facilitated through the cloud digital platform which the AWM system provides.

2.2 AWM Cloud Platform

This section will discuss various key features of the AWM system hosted on cloud platform. The AWM cloud platform provides cloud storage services which offer a scalable, security-rich and cost-effective home for the massive road data. The digital platform is adjustable in terms of capacity and optimize performance as requirements change. AWM also provides databases and integrations to support building or migrating a wide range of application and database types like videos, images, text and others. For example, our technicians use gadgets like GoPro cameras to capture high resolution images and videos or the TotalPave phone application to pick up IRI data which can be easily uploaded to the database in its different formats. Another key attribute to the AWM system is its analytics functions. Various applications such as the bridge management software, monitoring and evaluation function or HDM4 analyze the data and produce required results which is used to guide decision

making in network planning. Other cloud capabilities will be incorporated as the AWM system advances in the future.

Figure 2 below shows the basis architecture of the AWM system with current and future development expectations. Note that the source is from internal document between DOWH and the system’s developer. Access to the source can be through DOWH.

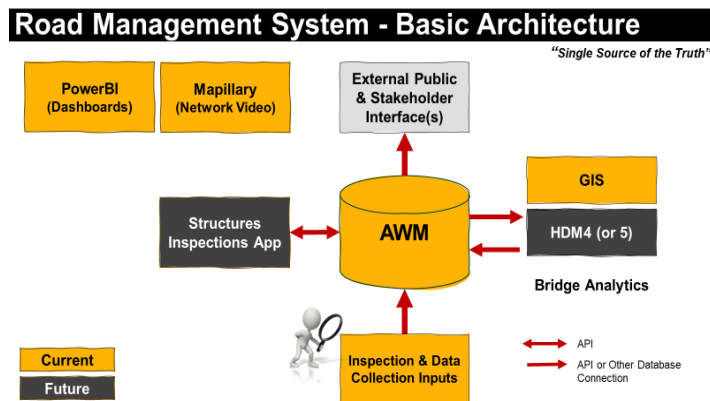


Figure 2 Basic architecture of AWM system (Gough, 2025)

3. IMPACT OF CLOUD COMPUTING IN DOWH

The Department of Works and Highways is Papua New Guinea’s leading government agency responsible for developing, managing, and maintaining the nation’s road and transport infrastructure including building infrastructure such as hospitals and schools. As the backbone of economic growth and social connectivity, DOWH ensures that every citizen has access to safe, reliable, and sustainable transport networks. To ensure effective implementation of the department’s goals or objectives, the use of the ICT and DT is crucial. Basic types of ICT and DT services used in the organization include intranet, website, cloud technology, servers and data storage facility for road and bridge data such as condition surveys, design information, road and bridge inventory and so forth.

The Department is embracing cloud computing as part of the broader PNG Government Cloud Policy. This policy aims to streamline government operations by utilizing cloud services for infrastructure and software as a service. The Department of Information and Communications Technology (DICT) is responsible for coordinating the implementation of the cloud platform for all government departments, including the DOWH. The impact of Cloud Computing in DOWH particularly through the implementation of its road projects and programs is critical. It includes enhancing infrastructure through ICT, improving project management efficiency, and strengthening governance and accountability. The program leverages technologies like GIS, real-time reporting, and automated systems to track progress, identify bottlenecks, and ensure projects stay on schedule and within budget. The diagram below illustrates a typical cloud platform.

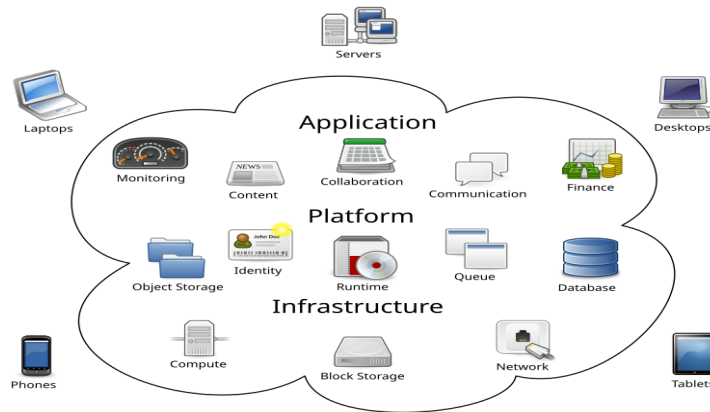


Figure 3 Overview of cloud computing, with typical types of applications supported by that computing model (Johnston, 2020).

Four key impact areas cloud computing is having in DOWH is as follow;

1. ICT Enhancement of Infrastructure

DOWH is integrating ICT into its operations to improve infrastructure development and maintenance. This includes using Road Asset Management Systems (RAMS) and Bridge Asset Management Systems (BAMS) to optimize resource allocation and make data-driven decisions. Note that both the RAMS and BAMS systems have been integrated to one system called the Asset and Work Manager. Having road and bridge inventory together with other relevant data sets like traffic volume, safety, pavement, structure and others ensures effective network planning.

2. Project Management Efficiency

Digitalization of procurement processes and project dashboards, along with the integration of Internet of Things-enabled monitoring systems, are streamlining workflows and providing real-time project tracking. Projects reports uploaded on site using android phones or tablets with inbuilt reporting templates onto AWM cloud server from the provinces and accessed by Headquarter to prepare reports for senior management and the government including relevant stakeholders.

3. Governance and Accountability

The program uses GIS and real-time reporting tools to track project progress, identify bottlenecks, and ensure projects stay on schedule and within budget. Regular audits and compliance checks are conducted to uphold financial integrity and operational efficiency. In the past records are kept in hard copies or sometimes in electronic format but with different people. The AWM system enables all project reports including design information, contract agreements and other critical information to be easily stored and accessed, hence improving and promoting accountability.

4. Capacity Building

DOWH is investing in training programs to upskill its workforce in modern engineering practices and equip them with digital literacy. The cloud digital platform is a new technology that is making its way into PNG and DOWH although its existence dates back means that DOWH technicians must be knowledgeable to run the system, hence contributing to achieving the department’s objectives or goals. Note that while the focus of this case study is mostly on the impact of cloud platform on the engineering side of things, other operational functions of ITC have also been impacted by cloud. For example, the government’s financial management system called the Integrated Financial Management System (IFMS) is fully automated and is done one line today as opposed to manual processing in the past which is labor intensive and time consuming, thus delaying service delivery. The Government of Papua New Guinea

(GoPNG) is using digital transformation to change public administration processes, culture, and citizen experiences using information and communications technology (ICT) advancement as an enabler (DICT, 2020). The impact of cloud computing in DOWH is significant and it looks to advance even further in the future which means the department must be prepared to adapt with the evolving digital technology.

4. CHALLENGES OF CLOUD COMPUTING IN DOWH

Despite the progress made in the use of ICT and DT, significant challenges remain in effectively adopting technology into workplace such as digital divides, inadequate digital literacy, and insufficient professional development for professionals are common barriers. These barriers emphasize the importance of high-speed internet, and ongoing training and development opportunities for professionals, which are crucial for the effective use of ICT and DT in undertaking their day to day work. Professional organizations must prioritize addressing these gaps through targeted investments in infrastructure, professional development, and digital literacy initiatives (Kennedy, 2025).

Cloud computing adoption in PNG's Department of Works and Highways faces several challenges, including lack of planning, limited expertise, and security concerns. These challenges are compounded by the department's unique context in PNG, such as budget constraints, environmental pressures, and the need to adapt to changing workforce structures. These challenges are explained below.

1. Lack of Planning and Expertise

Many cloud implementations fail due to inadequate planning and a lack of expertise within the department. This includes insufficient training for employees and a lack of clear understanding of how cloud services can be best leveraged for infrastructure projects.

2. Security Concerns

Cloud security is a major concern, especially with sensitive infrastructure data and projects. Ensuring data protection, compliance with relevant regulations, and mitigating cybersecurity threats are crucial for successful cloud adoption.

3. Inadequate Internet accessibility to all 22 provinces

Internet accessibility to all 22 provinces of PNG is not efficient and sustainable as cloud platforms depends on it. Setting up infrastructure in all provinces remains an ongoing challenge.

4. Budget Constraints

Limited government funding can hinder the implementation of cloud infrastructure and delay critical infrastructure projects, requiring innovative solutions to optimize resource allocation.

5. Environmental Factors

PNG's unique geographical and environmental conditions, such as its rugged terrain and susceptibility to natural disasters, necessitate the integration of climate-resilient designs into infrastructure planning and construction, which may require specialized cloud-based tools and expertise.

6. Workforce Adaptation

The department's evolving role from direct service delivery to a supervisory and regulatory body, as well as the adoption of outsourcing models, requires adapting to new technologies and ensuring contractors adhere to national standards using cloud-based solutions.

The introduction of cloud technology in the modern age requires the department to keep up with the knowledge trend in terms of upskilling its manpower and being creative in finding solutions to the challenges so that it can continue to operate it and remain relevant with the rest of the world.

5. OPPORTUNITIES OF CLOUD COMPUTING IN DOWH

Despite the challenges covered in the section before, cloud computing offers significant opportunities for the Department of Works and Highways (DOWH) to improve efficiency, enhance project management, and streamline operations. Key areas include leveraging cloud-based platforms for improved road network planning, real-time project monitoring, facilitating secure data exchange between agencies, and enabling remote access to critical information, ultimately contributing to better service delivery and citizen engagement. These opportunities are presented as follows;

1. Road Network Planning

The utilization of cloud platform to store and manage road data is crucial. Road and bridge data collection using relevant software and field-based applications, design software, accessing data remotely through cloud. Analytical applications dissect and analyze data to inform and drive business decision making, in this case the government can be better guided in terms of providing budget for road development and maintenance programs.

2. Project Management & Monitoring

Implement cloud-based project management tools to track progress, manage budgets, and ensure accountability across all projects. The AWM system has inbuilt monitoring and evaluation function which ensures field engineers to update project reports using field-based applications downloaded onto tablets and upload to the main cloud platform which is then analyzed and automatically produces consolidated reports for senior management within DOWH and GoPNG.

3. Data Sharing and Collaboration

Utilize cloud services to facilitate secure data exchange and collaboration between different government agencies and stakeholders involved in infrastructure projects, promoting interoperability and reducing duplication of effort. The sharing of information will ensure proper planning for maximum social and economic output. Through the AWM system, its cloud platform will enable other government departments to have access to the road network development plans for the long term and can integrate their plans accordingly. For example, the Department of Agriculture can plan their investment in parts of the country where the road network is developing.

4. Remote Access & Accessibility

Enable remote access to road data, project data, policies, and development and maintenance plans for DOWH staff and the public, enhancing transparency and accessibility.

5. Smart Infrastructure & Real-time Monitoring

Introduce smart infrastructure systems, including sensors and monitoring tools, to track road conditions and usage in real-time, ensuring timely maintenance and optimizing resource allocation.

6. Digital Transformation

Embrace the "Cloud First" approach to leverage current and emerging technologies to further enhance and digitize DOWH processes and operational mandates.

7. Cost Reduction

Reduce ICT investment costs by utilizing the Government Cloud Platform, a sanctioned platform for government departments to deploy cloud solutions. Cloud platform handle much of the infrastructure management as this is common in managing on premise servers, thus freeing up IT staff to focus on other tasks.

8. Enhanced Service Delivery

Improve service delivery to citizens by providing real-time updates on project status, enabling public feedback, and making key information easily accessible.

The opportunities discussed in this part of the study proves that the department can harness them into achieving its objectives. The government investment in roads has always been a challenge in terms of justifying its social and economic benefit. Today, road data is collected, stored and analyzed aided by cloud platform to ensure evidenced based decision-making, therefore yielding high social and economic returns for the country and its people.

6. CONCLUSIONS

Joseph Carl Robnett Licklider is considered to be the father of cloud computing. In 1960, he developed ARPANET, a precursor to the internet. By developing ARPANET, he introduced the concept of time sharing where multiple users share computing resources. This groundbreaking invention has now given businesses including government organizations the competitive edge to store and manage their data which is then used to guide them in making sound business decisions ensuring objectives or goals are met.

The Department of Works and Highways is also embracing the cloud platform in storing and managing its road data as well as facilitating its operational requirements like financial management system and HR system. Choosing which road to invest in may seem an easy decision for the National Government of PNG to make because these days everyone needs a road, however given the resource constraints, not all roads can be built any one time. It calls for strategic network planning where roads based on its high social and economic value is most likely to be considered first then the others. Transport economics is based on the idea that the economic return on a road built is used to build another new road. A branch of this concept also states that sustaining the existing network through regular maintenance is critical as it is already generating revenue for the country. Wise thinking would recommend sustaining the existing network to developing a new one. But the question remains, how does one make these investment decisions? The answer is simple, what does the data tell you?

In the past, the Department of Works and Highways has had no proper road data storage and management mechanisms with proper analytical tools or software to analyze the raw data to guide the important investment decision making. This prompted the department to adapt the Asset and Work Manager system. A key feature of this system is that it is operates on a cloud platform which practically solves all the problems for road network planning in DOWH. Having 22 provincial establishments around the country and managing almost 30,000km of both national and provincial roads, the cloud platform provides the environment where data can be uploaded or accessed remotely. Analytical tools such as RAMS, BAMS and HDM4 are inbuilt into the system where the raw data can be analyzed to produce expected results. Additional software depending on the complexity of task can be integrated into the system, thus making the network planning more efficient than ever.

The cloud platform has brought about many opportunities such as improving access and collaboration, increase flexibility and scalability, enhancing security and reducing cost. However, just like any new digital technology, there are challenges that the department must address such as lack of expertise, poor internet accessibility, data security threats, budget constraints and others. These challenges can be solved through creative thinking, capacity development, collaboration with cloud service providers such as PNG DataCo, improve internet accessibility and open dialogue with all stakeholders.

This study has been able to discuss the key objectives in terms of the impact, challenges and opportunities of cloud computing in the Department of Works and Highways. I have also provided an insight into the Asset Work Manager system which is the backbone of network planning aided by cloud platform. The use cloud and other digital technologies is here to stay with further developments and advancements expected in the future, therefore the department must remain receptive to the changes and will use the technology to its advantage while at the same time managing the challenges.

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