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A Case Study of Smart Car Park Management System at PMIA Using AI

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Abstract: Airport car park is a vital service component of airport operations, directly affecting passenger satisfaction, and is a major contributor to the airport's non-aeronautical revenue portfolio. At Port Moresby International Airport (PMIA), the traditional parking management faced challenges in congestion, manual operations, and non-aero revenue leakages from car park operations. In response, the National Airports Corporation (NAC) initiated the implementation of a smart car park system project to enhance efficiency, security, and customer experience, while also expanding the commercialization of the airport car park to generate non-aeronautical revenue. This paper presents PMIA's car park system project as a case study, outlining challenges, technological interventions, and anticipated benefits for Papua New Guinea's (PNG) aviation sector.

Keywords: *AI, ANPR, Car Park, Deep Learning, Commercialization, NAC, PMIA, Smart Airport, Tap way.*

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I. INTRODUCTION

Airports serve as gateways to nations, and their infrastructure reflects the operational efficiency and seamless customer experience of these gateways. While aeronautical (primary) services, such as terminal modernization and runway upgrades, often take precedence over non-aeronautical or secondary support services, such as car parks, which are also equally critical to enhance the overall customer experience and quality of service at the airport (Manuela Jr. & Friesen, 2025).

Airport car park remains an important landmark that provides a link between accessing terminals from the landside (Graham, 2018). As an essential airport service, efficient car park management ensures the smooth flow of passengers from the landside to the terminal and vice versa. Proper car park management ensures secure vehicle movements in airport precincts, while guaranteeing safety and security for the travelers and their vehicles (Wang, Kong, Bilotkach, Karanki, & Gao, 2025).

To address the manual car park management, smart parking is becoming increasingly adopted and implemented by many airports globally. Today's modernized airports utilize smart technologies to digitalize airport services, for example, the airport car park to improve operational efficiency. Examples of these smart technologies include Artificial Intelligence (AI), Machine Learning (ML), Internet of Things (IoT), cloud computing, and other digital technologies that are adopted to automate airport business processes and services to make them smarter (Thangamariappan, Balaji, Dhanusu , & Hariprasath , 2025) (Mane, Bhusagare, Kaname, Dhende, & Gavhane, 2024).

This paper provides a case study into the car park project from business value to system design, implementation, and how it transforms airport operations efficiency and non-aeronautical revenue at PMIA. More specifically, this paper discusses the adoption of an industry-specific AI-based Automatic License Plate Recognition (ANPR) system that integrates with AI models, utilizing deep learning and ML algorithms for car park management at the PMIA (Tapway, 2023).

We use a practical case study approach to present the findings, implementations, and observations for this airport paid car park project. The findings from this case study at PMIA offer insights into project management techniques and approaches, including lessons learnt from the adoption and implementation of these smart technologies to commercialize business service in a controlled environment such as an airport where regulatory compliance, safety and security remain high. This will guide future similar project implementations here at Papua New Guinea (PNG) airports as well as contribute to a body of knowledge that other global airports can learn from and adapt to improve their non-aeronautical business.

The remainder of this paper is structured as follows: Section 2 discusses the background of car park management and operational challenges at PMIA. Section 3 discusses in

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detail the implementation of car park management at the PMIA car park using the digital technologies and services that are deployed for this managed service. This included the business processes and the service delivery approach, apart from the intelligent services and system components deployed for smart car park management at PMIA. Section 4 discusses benefits, business value, implications, and observations from implementing the smart parking system and its commercialization at PMIA. This also includes the project's overall contribution to improving airport operational efficiency and business value from both operational and commercial perspectives. Section 5 discusses lessons learned for other airports, and finally, Section 6 provides a conclusion and future recommendations, followed by references in Section 7.

II. PMIA'S CAR PARK OPERATIONAL & MANAGEMENT CHALLENGES

PMIA, the primary air gateway to PNG, has undergone modernization upgrades in recent years; however, the commercialization of the airport's public car park facility was not operational. The car park management portfolio, as a significant contributor to the non-aeronautical revenue stream, was introduced, managed, and operated by the Commercial Division of NAC at PMIA in March 2019 and ended in November 2020. During that time, a ticket-based system was used to monitor park time usage upon entry of the vehicle and exit, and the length of stay (LoS) time was calculated upon exit, and payment was made accordingly (Papayiannis, Johnson, Yumashev, & Duck, 2018). Upon entry, the camera reads the vehicle's plate number and automatically issues a ticket (timestamping the entry time) before the barrier arm opens for entry. When the vehicle exits, the owner presents the ticket to the pay station, and the charges are calculated and paid before exiting.

The commercialization of the car parking into a paid parking service was progressing smoothly with significantly higher revenues reportedly generated from the paid car park alone; however, in 2020, car park operations were disrupted due to the COVID-19 pandemic, after which the then NAC management decided to decommercialize the paid car park at PMIA.

Since then, the airport operator has left the car park to become a free parking zone without any proper management, as it was initially. This left the car park open with no secure vehicle access control and limited car park monitoring within the airport car park facility, posing high operational, safety, and security risks due to limited surveillance and weak enforcement of movement control at the car park. Furthermore, parking at the airport was managed manually, with minimal automation or real-time monitoring and no tracking of vehicular movement for real-time response to operational needs at the car park. This leads to several more challenges, including congestion during peak hours due to manual classification of vehicles by humans, unauthorized/unlicensed vehicle access, and a general lack of user convenience posed by limited parking space. With increasing passenger and aircraft movement growth, the demand for a more efficient parking system has become increasingly greater.

Car parking revenues are an important source of non-aeronautical revenue for the airport (ACI, 2023). Subsequently, since the primary motive to enhance this service for commercial purposes was not realized, its service level dropped, and its related revenue generation was not realized, thus resulting in NAC missing out on the commercialization of the car park for many years. Revenue losses due to a lack of control over the car parking area and non-commercialization of the parking service add value to the business service.

There is also a lack of real-time data analytics on parking capacity and movement, and strategic planning to cater to airport security and compliance needs related to airport operations at the car park. Such data is crucial to airport managers for planning future airport expansion and supporting new airport development initiatives, both from operational and commercial perspectives.

Recognizing that the airport car park remains one of the vital areas of airport operations management that requires innovation for proper car parking management, NAC is now implementing a smart car park system at PMIA to address operational inefficiencies and to expand non-aeronautical business streams through the commercialization of the parking facility.

III. IMPLEMENTATION OF THE SMART CAR PARK SYSTEM

Coupled with the operational inefficiencies, followed by the need to expand the commercial revenue, including the desire to make airports smarter, and strategic airport planning incentives, NAC adopted a phased approach to recommence the modernization and the commercialization of the PMIA's paid car parking facility in 2024. This time, utilizing an Automatic Number Plate Recognition (ANPR) system, a smart digital technology to automate the car park management for seamless tracking, monitoring, and processing of vehicular movements within the airport-designated car park facility. The car park management system at PMIA employs Tapway's Vehicle Track platform, which uses cameras and computer vision algorithms for vehicle movement tracking, identification, and monitoring (Tapway, 2023).

The main components, as illustrated in **Error! Reference source not found.** 1 include the physical car park infrastructure and the facility. The ICT infrastructure components play a crucial role in ensuring that the entire car park facility is fully integrated and functional. This includes network infrastructure, vehicle recognition system, payment portal, and other related application components of the system deployed for car park management.

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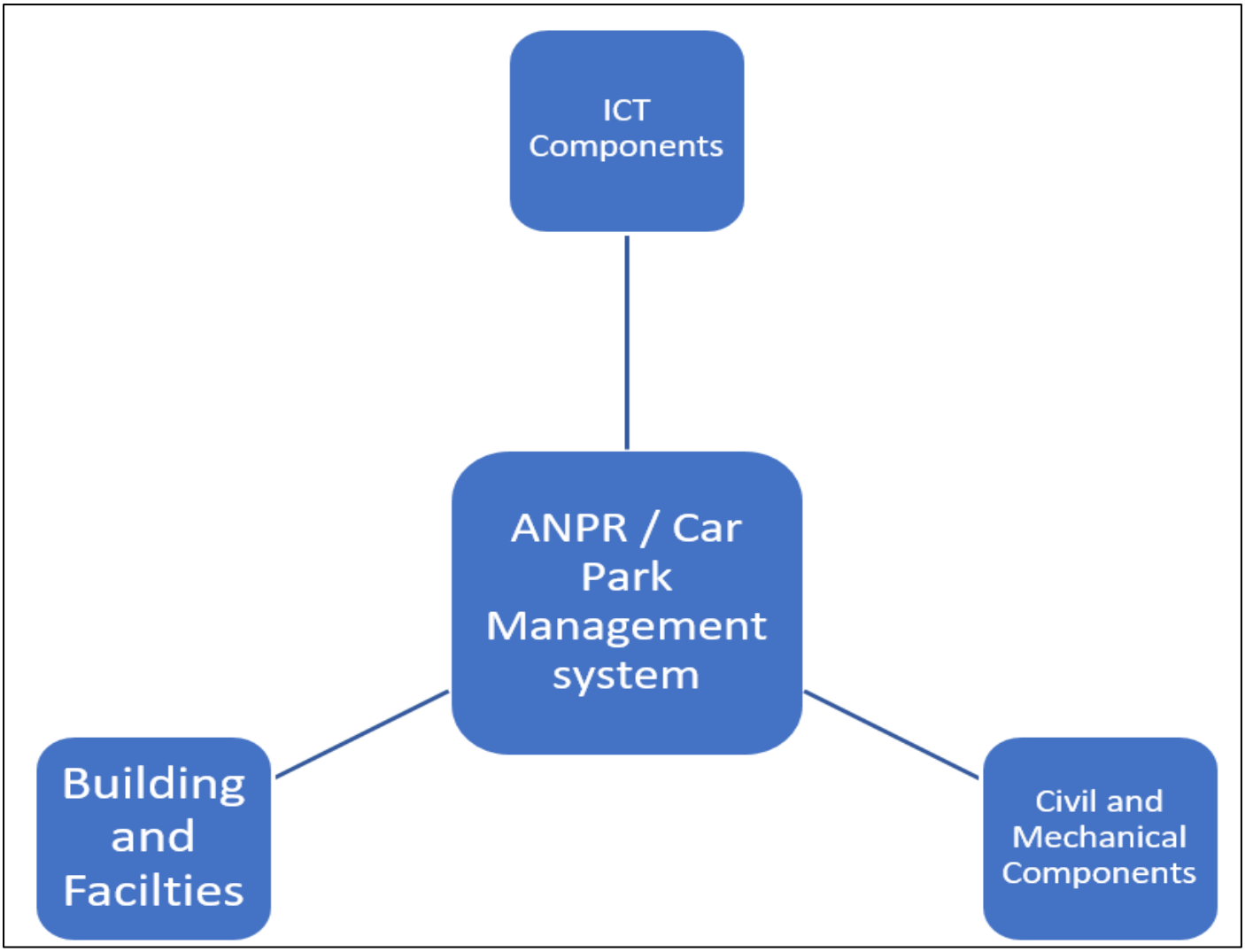

Fig 1 PMIA's Car Park Management Key Components

The project was scoped and implemented in four phases. The first and second phases of the project are the infrastructure and facility component upgrade. This includes building parking lane markings, boom gates, humps, notice boards, pay station upgrades, and other civil and mechanical works associated with the car park facility upgrade.

The second phase includes ICT Components. This comprises the installation of barrier arms at entry and exit points, camera installations, power upgrades, servers and PC installations, and the designation of short-term, long-term, and staff parking areas.

The third phase comprises technology integration. This phase involved the installation, configuration, and integration of ANPR software and payment system interface.

The final phase includes system testing, awareness, dry runs, and preparation for go-live.

The project started in November 2024, with completion and commissioning in December 2024, with added variation works taking another two months. Finally, the project was launched and went live in February 2025.

- *System Design & Process Flow*

Fig 2 shows the system design and process flow of the paid parking system deployed at PMIA. It describes the ANPR parking management system with its components in detail.

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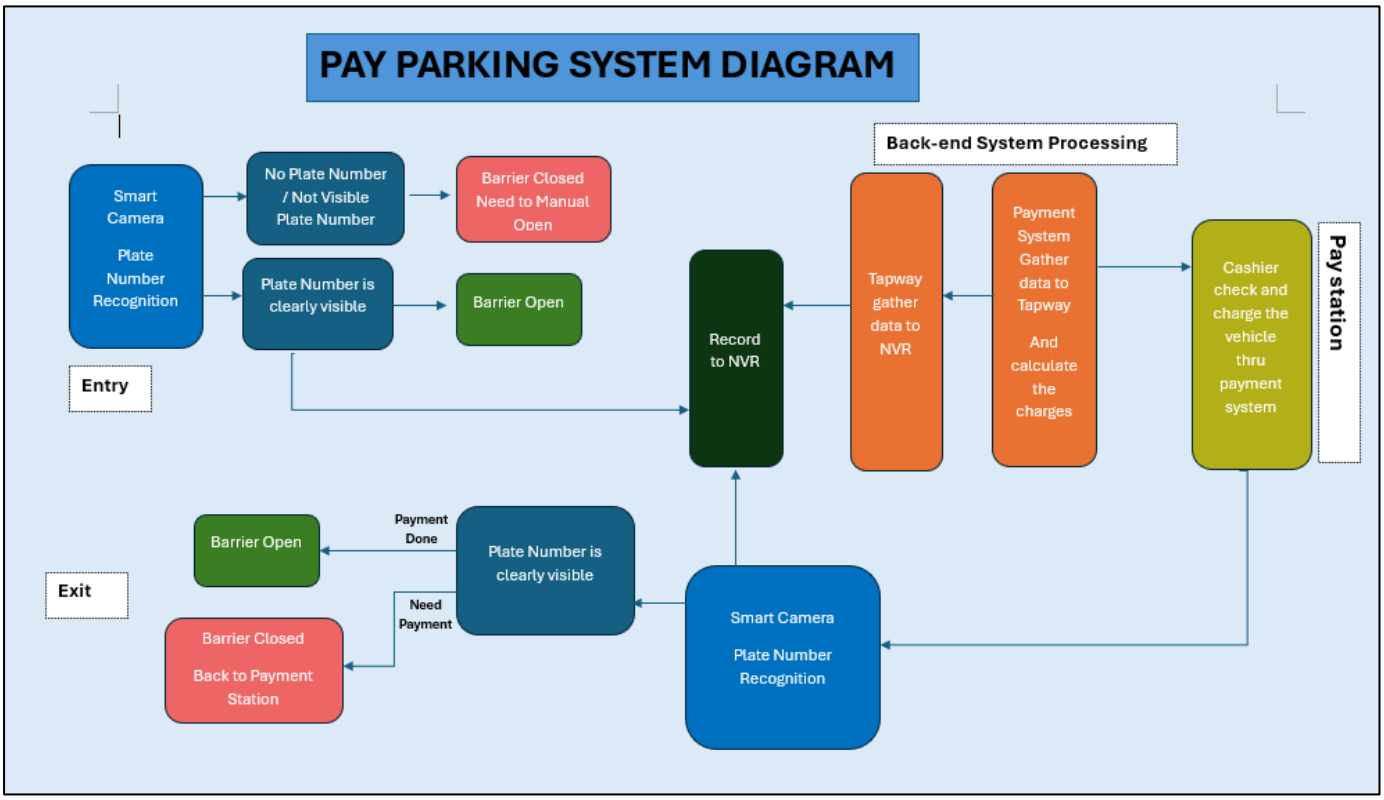

Fig 2 PMIA Paid Car Parking System Diagram.

The system deployed uses the Tapway VehicleTrack platform, an ANPR system powered by deep learning technologies integrated with the network video recorder (NVR) to smart IP cameras for handling vehicle detection and classification, which processes unstructured raw data (Tapway, 2023). Furthermore, the system integrates multiple camera points with sensors at entry and exit gates, which is integrated with the payment system for calculating the charges for the parking duration. (Tapway, 2023), (ACI, 2022) (Shinde, Shinde, & Shaikh, 2018).

The paid parking system uses an ANPR system that is embedded with deep learning algorithms to capture, monitor, identify, track, and manage vehicle movement within the airport parking area. Compared to conventional computer vision processing, Tapway's ANPR embeds deep learning algorithms that achieve much higher accuracies with fast processing time in processing raw, unstructured data (Tapway, 2023).

➢ *Key Components of the System Include:*

- High-resolution cameras and sensors at entry and exit points integrated with NVR
- ANPR vehicle tracking software for real-time number plate recognition, which uses deep learning models for data processing in real time.
- Cloud-based database integration for vehicle tracking analytics
- Payment interface and portal for capturing, tracking, and monitoring payments and sales records.
- Web interface for real-time vehicle movement tracking integrated with NVR cameras.
- The deployment of deep learning algorithms for the ANPR system with the NVR and cameras at the entry and exit gates to coordinate with the car park system to register an entrance by the plate number, calculate the parking charges for the parking duration, and also give clearance for the exit gate upon camera detection of the plate number. This algorithm helps process data in real-time, particularly useful where vehicular plate numbers are sometimes not aligned well, characters are misplaced, and other related issues with plate numbers, where image processing tasks happen in real time for access into the car park (Tapway, 2023) (Bui, Alaei, & Bui, 2019).
- As depicted in Fig 3, upon entry, the camera reads the car plate number and registers before the barrier arm is opened for the car to access the car park. Before exiting, the driver checks the pay station for the duration of the vehicle parking time, and if it exceeds the free time of ten minutes, the driver will be required to pay the calculated parking charges before exiting. When exiting, the camera reads the plate number, checks the parking in the database and the payment records, and allows the barrier arm at the exit gate to open for the vehicle to exit the car park. If the vehicle has exceeded the free 10-minute limit and has not paid its charges, the barrier arm will not open, and so the driver will have to check with the pay station for payments to be made before exiting, as seen in Fig 3, which summarizes the process flow into the airport paid parking facility.

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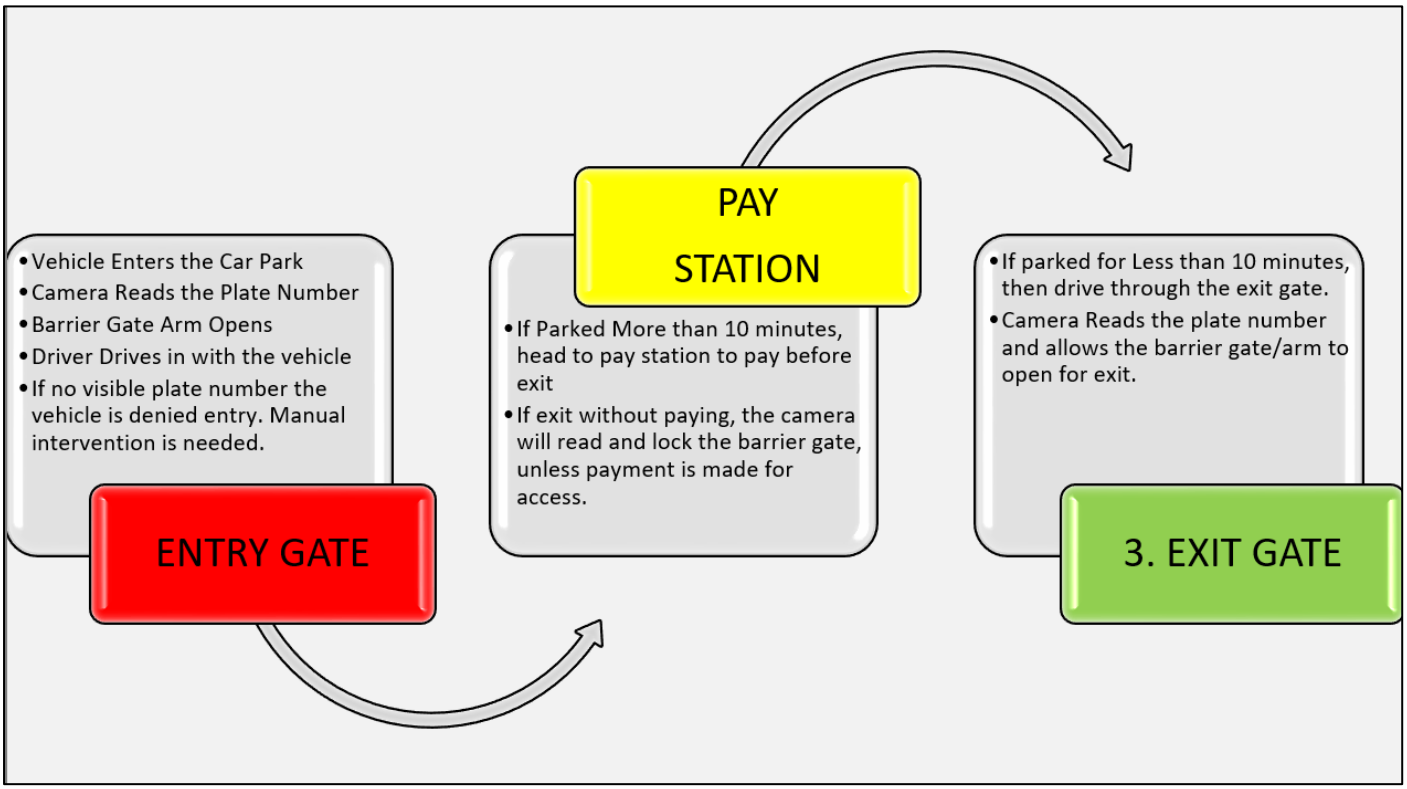

Fig 3 PMIA Paid Car Park Process Flow.

IV. BUSINESS VALUE OF THE COMMERCIALIZED SMART AIRPORT CAR PARK MANAGEMENT

This section discusses the business outcomes and benefits, and observations of the commercialized smart car park management system at PMIA from operational and commercial viewpoints.

➢ *Smart Airport Technologies for Smart Car Park Operations*

The digitalization of car park management services improves airport service offering to the customers, including a better service experience. As summarized in Fig 4, the adoption of digital technologies for car park management, using the latest intelligent digital technologies to automate airport business processes and services, making them smarter (Narongou & Sun, 2022).

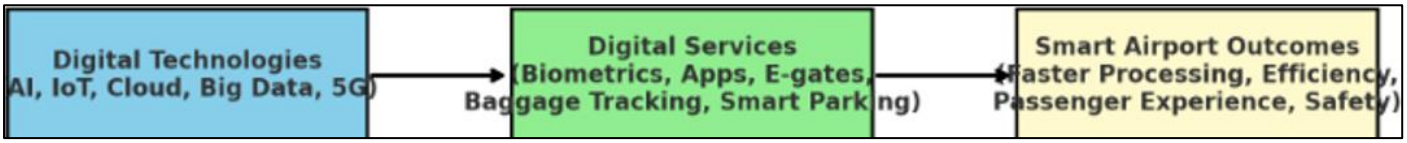

Fig 4 Digital Technologies for Smart Airport.

The adoption of digital technologies enhances the operational and management aspects of airport car park service and whilst at the same time increasing the business value of the service offering to the customers and the airport operator. The use of AI, specifically deep learning models/algorithms, in capturing and processing vehicular data marks the first instance of AI capabilities being utilized at PNG's international airport. This is a significant step towards a smart airport initiative, promoting the adoption and implementation of smart technology. This positions NAC to be on a pathway to increasingly adopt smarter technologies to manage its 22 airports nationwide sustainably (Narongou & Sun, 2021).

➢ *Revenue Management and Control*

The commercialization of the paid car park generates an additional non-aeronautical revenue stream for the airport operator. The ACI's Airport Economic Report stated that the airport's car park is also a significant revenue stream for the airport operator. Almost 21 percent of airports' non-aeronautical revenue is generated from car park charges or parking fees (ACI, 2023). The commercialization of paid parking at PMIA resulted in optimized revenue collection. Projections from PMIA's car park revenue could potentially generate up to a million kina annually, contributing to increased non-aeronautical revenue for the airport operator.

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The automated rate calculations for payments by the system helped minimize the risk of fraud and revenue leakage through automated payment systems, and transaction reports are logged and reconciled for billing purposes. Price setting and fee charges are inputted into the payment system, interfacing with Tapway's ANPR, which provides a deterministic monetary value for car park charges, which is processed automatically.

➢ *Airport Operational Efficiency and Sustainability*

Faster vehicle throughput at entry/exit with limited human involvement. Improved traffic flow by reducing waiting times and congestion. Passenger experience: Easier and quicker parking, aligning with international standards. On the other hand, it promotes enhanced security for the airport operator and the customers 24/7. This has contributed to improve monitoring and wide area visibility of the car park area in the control room, reduced unauthorized access, and automatic vehicle tracking within the parking area (Tapway, 2023). On one hand, to avoid paying fees due to longer parking time, the vehicle comes, drops off, and then drives away. This contributed to reduced fuel emissions and enhanced an environmentally friendly airport in PNG.

Furthermore, the paid parking facility at PMIA is now outsourced, with the operations and management of paid car parking to an agent to manage the operations of the car park. Outsourcing adds more benefit to in-house staff by reducing the burden and workload to focus on critical non-aero business initiatives and opportunities. Outsourcing reduces workload, eases coordination, and reduces other costs related to direct management by NAC (Osagie, Emeka, & Beatrice, 2023).

➢ *Data-driven Capabilities for Strategic Planning*

Compared to other previously manual operations and the ticket-based system, the use of ANPR simplifies system data capturing and processing, and operations without much manual intervention. The use of smart technologies has captured real-time vehicle movement data and processed and analyzed the data with centrally managed capabilities.

With the automated car park system being adopted, the availability of car park data for operational monitoring, revenue billing, and strategic planning is now readily customizable and accessible at an instant, which was not previously possible. The data analytics (data-driven insights) solutions enhance the availability of real-time vehicle movement and transaction data for reporting and capacity planning, billing, and strategic monitoring.

V. LESSONS FOR OTHER PNG AIRPORTS

This section describes lessons learned from the system implementation and the implications of the smart car park management at PMIA, and the way forward for expansion to other regional airports' car park operations, and the commercial viability of airport business value.

➢ *Expansion of Automated Paid Parking Service to Regional Airports*

Expanding the implementation of a similar project in its Class a Airports, including Nadzab Tomodachi International Airport (NTIA), in the near future to improve operational efficiency, safety, and security, and to generate additional non-aeronautical revenue for airport development initiatives. Smart systems can become a model for regional airports in PNG, starting with mid-sized hubs like Nadzab and Tokua, to have a unified smart airport in PNG. PMIA's case study demonstrates immensely huge benefits and also challenges for continuous improvement for consideration when expanding this similar technology to enhance other key regional airports' car parks in PNG.

- Automation reduces dependency on manual labour while improving accountability and visibility into airport processes and services.
- Create a new airport revenue portfolio to fund ongoing improvement programs through revenue generated from the car park and contribute to long-term airport sustainability, and diversify airport service offerings.
- From the project management viewpoint, a phased, scalable approach allows gradual implementation despite budget constraints, and managing project scope creep must be carefully considered. As is the case with many projects, scope creep, with its impact on overall project budget and implementation costs, and time of delivery, is another challenging factor faced by all project managers (Ravi & Donawa Jr, 2021).
- Centralized hub and spoke and unified /integrated car park management system to be monitored from PMIA. This includes all security monitoring aspects, such as CCTV with real-time alerts for quick response by airport security personnel (Narongou & Sun, 2021).

➢ *Future of Airport Car Park Management*

As a smart technology initiative to make airports become smarter, this positions NAC to market PMIA and its other key airports as a forward-looking hub embracing digital transformation in their operations. Potential challenges include initial setup costs, system integration with legacy infrastructure, and user acceptance levels of new technology. These can be mitigated through proper planning, stakeholder engagement, and capacity-building initiatives that are scalable at PNG's airports' car parks that support passenger convenience, increase operational efficiency, and cater to future increasing demands in air travel.

- Security Enhancements – CCTV through NVR and smart camera surveillance and 24/7 monitoring linked to airport security systems, and an advantage for real-time engagement and reporting.
- Passenger and public convenience – Online booking, mobile payments, and digital signboards for space availability;
- Move towards electric vehicle charging stations and solar-powered car park facilities.

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- The implementation of an AI-driven car parking management system at PMIA is a significant step towards smarter airport operations in PNG. By embracing innovation and business sustainability, NAC can not only enhance service delivery but also set a benchmark for other regional airports in PNG and in the wider Pacific region.

VI. CONCLUSION

The implementation of a smart car park system at PMIA represents a significant milestone in PNG's aviation modernization efforts. The success of this project demonstrates that innovation starts by utilizing the available smart technologies to digitalize airport service, thereby converting them into airport business service that contributes to business process improvement for increased efficiency and improved business value to the airport operator (Narongou & Sun, 2022). By automating airport car park management and aligning with global airport standards, NAC has enhanced three facets of airport services holistically: operational efficiency, increased passenger experience, and optimized airport revenue management.

The success of this project demonstrates that even in developing economies such as PNG, innovation through strategic technology adoption in airport service areas such as car park, is both feasible and beneficial to achieve operational efficiency, diversifying sustainable business service offering to boost non-aeronautical revenues and strategic differentiation.

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