JEEP-PS: PIONEERING SMART MOBILITY SOLUTIONS THROUGH ADVANCED E-JEEP TRACKING TECHNOLOGY WITH ARRIVAL INFORMATION IN SELECTED TOWNS IN NUEVA VIZCAYA

A Capstone Proposal Presented to the Faculty of the
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INTRODUCTION

Rationale

Jeepneys, or jeeps, have been considered the backbone of transportation in the Philippines ever since they were originally made to be used by the U.S. military during WWII. These vehicles were then later modified into regular modes of transport by Filipinos, adding metal roofs for shade and painting them in vivid hues with chrome-plated side and hood decorations (Rabino, 2021). Jeepneys are not just practical modes of transportation; they are also living symbols of the Philippines' heritage and identity. Many jeepney owners adorn their vehicles with intricate paintings, often featuring vibrant scenes from Filipino culture, historical figures, or religious iconography. Jeepneys represent the resilient, innovative, and optimistic nature of the Filipino people, just as they travel both rough and dusty rural roads and busy city streets (Escalona, 2023). Filipino passengers primarily use jeepneys for transportation to get to their intended destinations in their everyday lives (Andalecio et al., 2020).

Jeepneys are commonly used due to their price, efficiency, and availability (Ong et al., 2023). Due to the vast number of jeepneys and jeepney drivers on the road at all hours of the day and night, jeepneys are commonly recognized as the most common and least expensive method of transportation in the Philippines. But despite

this, jeepney drivers are recognized as part of the lowest socio-economic standing group (Enriquez et al., 2022).

Furthermore, environmental concerns such as air pollution and greenhouse gas emissions from the combustion of fossil fuels have prompted countries worldwide to seek more sustainable transportation alternatives. Electric vehicles (EVs) have emerged as a highly promising technology in this regard, offering a cleaner and greener mode of transportation. In 2018 alone, over two million EVs were sold globally, and projections suggest a significant increase to 56 million by 2040. This transition towards electric mobility aligns with the global effort towards a sustainable energy transition and underscores the importance of exploring alternative modes of transportation, including e-jeepneys, in the Philippines (BNEF, 2019).

To combat the global challenges posed by greenhouse gas (GHG) emissions, air pollution, and reliance on fossil fuels, nations and regions are actively seeking cleaner and more sustainable transportation options. Presently, the transportation sector contributes to 23% of global energy-related CO_2 emissions and continues to expand due to rising levels of passenger and freight activity. Given the considerable difficulties in decarbonizing modes such as aviation, shipping, and heavy-duty roads, the electrification of passenger cars and public utility vehicles (PUVs) emerges as a promising solution to mitigate GHG emissions and pollutants (Agaton et al., 2019).

The adoption of eco-friendly vehicles such as electric jeepneys, over traditional public utility vehicles is gaining traction in the Philippines. Leveraging advancements in transportation technology, this shift aims to enhance the commuting experience by ensuring access to safe, clean, and efficient public transport for the population. These efforts are reflected in the establishment of structured vehicle requirements designed to address transportation challenges in specific areas, thereby contributing to the improvement of the Philippine transportation system overall (Villegas et al., 2021).

Accompanying the emergence of e-jeepneys is the integration of the Internet of Things (IoT) in transportation systems. The IoT enables real-time monitoring and data collection, allowing for more efficient fleet management, route optimization, and passenger safety enhancements. Through IoT-enabled devices and sensors, operators can gather valuable insights into vehicle performance, traffic patterns, and passenger behavior, ultimately improving the overall commuting experience.

The Transition to Electric Public Transportation in the Philippines

According to the website temboelv.com (2023, December 7), the Philippines is actively pursuing a transition towards sustainable public transportation by promoting the adoption of electric jeepneys (e-jeepneys) as an alternative to traditional diesel-powered jeepneys. The government has implemented the Public Utility Vehicle Modernization Program (PUVMP) with the primary goal of replacing internal combustion engine (ICE) jeepneys with energy-efficient and environmentally

friendly electric versions, particularly in the Manila metropolitan area and other urban centers. This initiative aims to address the challenges faced by the diverse public transportation system, such as air pollution, traffic congestion, and outdated infrastructure.

To facilitate this transition, the government has established financing mechanisms for cooperatives that operate jeepney services. Furthermore, the recently passed EVIDA law introduces a Comprehensive Roadmap for the Electric Vehicle Industry (CREVI), which includes significant incentives to produce electric vehicle components, the development of charging stations, manufacturing, research and development, and human resource development in the electric vehicle sector (temboelv.com, 2023, December 7).

The shift towards e-jeepneys is expected to result in substantial cost savings for both operating companies/drivers and passengers. According to the website, the energy cost for a diesel-powered jeepney ranges from PHP 1,500 to PHP 1,800 per day, while the cost for an e-jeepney is estimated to be around PHP 500 to PHP 700 per day for electricity, resulting in savings of more than PHP 1,000 per day per jeepney unit (temboelv.com, 2023, December 7).

E-Jeepneys

In collaboration with the Electric Vehicle Association of the Philippines (EVAP), a prototype for a 23-seater electric jeepney that complies with PNS was created. E-jeepneys, short for electric jeepneys, are an environmentally friendly substitute for a diesel-fueled jeepney, which runs on lithium-ion batteries and emits

no noise or emissions. E-jeepneys have a 55km range on a full charge. Its dashboard panel features an emergency button that disables the vehicle, an open and close side door button, and a standard LED display that indicates speed and remaining range. The non-metallic body materials of the ground-breaking e-jeepney are superior insulators with a strong resistance to chemicals and corrosion.

On May 2, 2022, a significant milestone was achieved with the introduction of these 23-seater electric-powered jeepneys to the public, marking a transition towards more sustainable transportation options. The demonstration of these e-jeepneys in Alabang and Muntinlupa showcased the potential of eco-friendly alternatives for commuting in the Philippines. Developed by engineers from the Electric Vehicle Association of the Philippines (EVAP) and supported by research, development, and prototyping provided by the Department of Science and Technology (DOST), these e-jeepneys signify progress towards cleaner and more efficient ways of public transportation (Juangco, 2022).

Furthermore, regulatory support from the Land Transportation Franchising and Regulatory Board (LTFRB) has paved the way for the operation of e-jeepneys in Nueva Vizcaya, particularly under the Modified General Community Quarantine status. Operating under the Point-to-Point route scheme, these e-jeepneys represent a tangible initiative toward integrating sustainable transportation solutions into local communities (Ebreo, 2020).

As the Philippines transitions to utilizing electric-powered jeepneys and sustainable mobility solutions, it not only addresses challenges such as air pollution, traffic congestion, and fuel dependency but also promotes economic inclusivity and environmental stewardship. The Department of Trade and Industry (DTI) and local non-governmental organizations may gain an interest in implementing e-jeepney trackers, primarily for compliance with the cooperatives and traffic rules, as well as safety and security reasons. Information about passenger demographics, traffic congestion, environmental impact, and e-jeepney usage patterns can also be gathered by the DTI. E-jeepney trackers can serve as invaluable tools for regulatory compliance, safety enhancement, operational efficiency, data-driven decision-making, and transparency in the public transportation sector. Implementation will align ensuring a safe, efficient, and sustainable transport system that meets the needs of all stakeholders.

Concerns regarding the sector's environment, safety, and efficiency have resulted in the establishment of the Public Utility Vehicle Modernization Effort, or PUVMP (Kritz, 2018). This effort is intended to modernize the entire sector and vehicle fleet. It aims to improve the existing public transportation system in the Philippines by reforming its practices, policies, business models, and cultural meanings. The program consists of ten components: regulatory reform, local public transport route planning for local government units, route rationalization, fleet modernization, industry consolidation, financing, a vehicle useful life program, pilot implementation, stakeholder support mechanisms, and communication. It is being

carried out in collaboration with over twenty local and international agencies (Mateo-Babiano et al., 2020).

The new design still preserves the look of the traditional jeepney but integrates modern features like air conditioning and a more efficient electric drivetrain. This ensures passengers enjoy a comfortable and environmentally conscious ride while also offering significant cost savings for drivers and operators. The vehicle can accommodate a total of 30 passengers (Guzman, 2023). This move to implement eco-friendly transportation is a big step for the Philippines, as it helps cut carbon emissions and protect the environment, while also making public transit better for everyone. The assistance of advanced technology in the scope of public transportation aids the government in improving the quality of traveling for commuters by considering the population to have access to safe, clean, and efficient public transport (Villegas et al., 2021).

Challenges of Jeepney Drivers

Managing passenger flow in public transportation is essential for ensuring public safety (Wang et al., 2019). Public transportation operators are facing significant difficulties in managing passenger flows, especially in populated urban areas where there is a high demand. The challenge in managing passenger flows on public transportation is making sure that vehicles are frequent and numerous enough to meet demand. Overcrowding or insufficient frequency can cause delays and longer wait times, which lowers passenger satisfaction. Ensuring passenger safety and

preventing disruption is essential, alongside managing the financial balance between operating costs and affordable fares. Effecting communication and collaboration among transport operators, authorities and passengers is essential for successful management (Romane, 2023). Finding creative solutions and taking proactive steps are essential to improve passenger management in public transportation. Implementing crowd control measures and utilizing technology for scheduling and communication can enhance the overall commuting experience.

Operating a vehicle of any kind is a complex task that requires significant shifts in mental focus and control. Since people's connections, entertainment devices, and navigation systems increase the amount of incoming information inside the vehicle, drivers must process a lot of information coming from outside the vehicle all at once, such as traffic intensity, traffic signs, and so on. (Enriquez et al., 2022) The development of common vehicles not only limits the driver to the main driving task and allows them to do secondary tasks (Meteier, 2021). They place individuals in the necessary conditions and keep an eye on them in various scenarios. However, it is stated that the addition of a secondary car might make the driver's mental workload heavier and possibly impair their performance. It is noteworthy to mention that research has indicated that verbal tasks can contribute to an increased mental workload for drivers. (Enriquez et al., 2022).

Efficient route planning plays a pivotal role in addressing traffic, enhancing road monitoring and safety, infotainment, and on-demand services. The goal of

efficient route planning involves optimizing routes to save time and resources, making your journey to destinations quicker and smoother. To determine the most efficient route, it requires consideration of factors such as distance, traffic conditions, and timing. It offers several benefits, such as better resource management and customer satisfaction, lower fuel costs, and a positive environmental impact (Patel, 2023). In a time when the efficient transportation of goods, services, and people is becoming increasingly important, route planning and optimization have become critical tools for individuals and enterprises. The ability to plan and optimize routes can significantly impact time management and overall productivity – whether it is for a driver, logistics manager, commuter, or frequent traveler (Saini, 2023).

There are also local transportation sectors, which serve as a crucial link connecting population and economic hubs across the islands of the Philippines, encompassing roadways, railways, maritime routes, and aviation networks (Guno et al., 2021). However, local transportation encounters a myriad of challenges as well, outdated infrastructure, aging vehicles, financial insecurity among operators, and a lack of structured support for modernization and development (Guevara, 2022). These challenges in the transportation sector are causing slow travel and frustrating traffic jams for people and businesses. Without enough support for modernization, the industry can't keep up with new demands and technology. We need to make big changes and spend wisely to fix roads, enhance operational efficiency, and foster transportation practices, by making these critical investments, the Philippines can

not only improve the efficiency of its transportation system but also stimulate economic growth and enhance the overall quality of life of its citizens.

Commuting in the Philippines

Public transportation in the Philippines, particularly in Metro Manila, is becoming a major issue as traffic congestion continues to increase (Bondoc et al., 2018). A vast number of individuals in the Philippines heavily rely on public transportation as their primary mode of commuting to reach their intended destinations (Peña, 2022). Commuters standing for hours in long queues waiting for transportation is a common experience. The Philippines has a massive public transport shortage, and even with conservative estimates of demand growth, regional areas continue to face a pervasive shortage in the overall supply of public transportation services (Chang et al., 2021). Apart from the availability of public transportation, commuters in the Philippines also face the challenge of unclear schedules. The lack of reliable schedules makes it challenging to organize their travels effectively, causing frustration and time wastage. Local transport service providers face challenges in improving their services due to a lack of theoretical understanding of service scheduling (Abad, 2014). The lack of reliability in public transportation is mainly due to inefficiencies within systems, particularly in scheduling and coordination. Delays, irregular service patterns, and the absence of synchronized timetables across different modes of transport all contribute to decreased effectiveness and efficiency (Nacpil, 2023). Addressing these issues with availability,

schedule clarity, and service efficiency is crucial for improving the overall quality and reliability of public transportation in the Philippines, ultimately enhancing the commuting experience for millions of individuals.

Commuters, the government, and the private sector all aim for seamless travel in the shortest amount of time possible. Ease of transportation has long been associated with economic growth; the faster goods and services are transferred, the faster the return on investment (Jocelyn et al., 2023). A commuter is defined operationally as someone who regularly uses public transportation to get to and from a destination. The longer commute time is one noticeable effect of the crisis on commuters, especially during rush hours (Fallaria et al., 2019).

GPS Tracking System

Global Positioning System (GPS) is a navigation system consisting of satellites and receivers that are used to determine a specific location on Earth (NGS, 2023). A tracking system using GPS enables the determination of the precise location of an object. In this case, such tracking devices can be installed in various vehicles, such as cars, trucks, boats, and other modes of transport. It can also be used for telematics and fleet management, providing real-time location data via a dashboard display or mobile application (Priyendran, 2022). GPS tracking technology makes fleet operations easier and better by removing the need for dispatchers to call drivers to find out where they are, dispatchers can access real-time location information through online dashboards. GPS tracks the acceleration, declaration, and speed or

how swiftly they pass through an intersection from any distance to monitor the speed of a moving vehicle (Rodela, 2022).

Even though both the electric and Liquified Petroleum Gas (LPG)-powered jeepneys comply with regulations, which could imply adherence to safety standards, modern jeepneys come with a range of safety features, such as airbags, seatbelts, and CCTV cameras (Golez, 2023). The modernized jeepneys are also envisioned to have a GPS (a satellite-based radio navigation system used to locate a vehicle) to boost passenger safety (Inquirer, 2023). Global Positioning System (GPS) data can be used to track the movement of modern jeepneys, potentially assisting authorities in responding to emergencies or incidents involving the vehicle. According to GMA Integrated News (2024) the potential for breakdowns due to the introduction of new technologies in e-jeepneys. GPS could aid in pinpointing the location of a stalled e-jeepney, allowing for faster dispatch of repair crews or alternative transportation arrangements.

Google Maps for Jeepney/E-Jeepney Tracking and Optimization

Mapping solutions like Google Maps offer a powerful complement to GPS tracking technology for optimizing the public transportation sector, including jeepneys and e-jeepneys in the Philippines. Google Maps provides a user-friendly visual interface to display the location and movement of vehicles along their routes. By integrating GPS data from jeepneys and e-jeepneys, Google Maps enables stakeholders, such as transportation providers, authorities, and even passengers, to

monitor vehicle fleets and their progress in real-time. This situational awareness can significantly enhance decision-making capabilities and overall operational efficiency.

Moreover, Google Maps offers access to valuable traffic data, which can be leveraged for intelligent route planning and optimization. By considering real-time traffic conditions, transportation providers can identify the most efficient routes, helping to minimize delays and congestion. This not only improves the commuting experience for passengers but also contributes to better resource management and cost savings for operators.

The integration of GPS tracking data with Google Maps can be achieved through the utilization of Application Programming Interfaces (APIs), allowing for the development of customized tracking applications tailored to the specific needs of the jeepney and e-jeepney transportation sectors. These applications can provide a centralized platform for monitoring vehicle locations, optimizing routes, and responding promptly to any incidents or breakdowns.

Furthermore, the user-friendly interface of Google Maps can potentially enhance the commuting experience for passengers by providing real-time information on vehicle locations and estimated arrival times. This transparency can help commuters plan their travels more effectively and reduce frustration associated with uncertainty or delays.

GSM Module

A GSM module is crucial for enabling communication between a computer and the GSM network, a widely used mobile communication system worldwide. This module includes a GSM modem, a power supply circuit, and interfaces like RS-232 and USB for connecting to a computer. It requires a SIM card, much like a mobile phone, to connect to the network, and each modem has a unique IMEI number for identification. The GSM modem can perform various functions, such as receiving, sending, or deleting SMS messages on the SIM card, managing phonebook entries, and making or receiving voice calls. Interaction between the modem and a processor or controller is achieved using AT commands sent through serial communication, with the modem executing these commands and returning results. These AT commands allow the computer or controller to interact with the GSM networks, supporting a wide range of functions. Integrating GSM technology into systems enhances their ability to communicate over mobile networks, making it vital for applications like remote monitoring, telematics, and wireless data transmission (Bhatt, 2019).

GSM Module plays a vital role to our system, it ensures tracking of E-Jeepneys, providing accurate arrival and departure information essential for passenger convenience and operational efficiency. By leveraging GSM technology, the system can send real-time location data to a central database, allowing operators to monitor the movement of e-jeeps across various routes. This real-time data transmission capability supports timely updates and alerts, enhancing the overall reliability and efficiency of the public transportation system. The GSM module's ability to manage

voice calls can be utilized for emergency communication, adding an extra layer of safety for passengers and drivers alike. The robust functionality and versatility of the GSM module make it indispensable for the advanced e-jeep tracking technology envisioned in the JEEP-PS project, thereby revolutionizing smart mobility solutions in Nueva Vizcaya.

GPS Module

The Global Positioning System (GPS) is a technology that has significantly revolutionized various industries, including transportation, logistics, and outdoor sports. The key to leveraging GPS technology is the GPS module, an electronic device that interacts with GPS satellites to provide geographical location data. GPS modules operate by utilizing a network of satellites orbiting the Earth, which transmit precise microwave signals. The accuracy and precision of GPS modules depend on several factors, including the quality of the GPS module, atmospheric conditions, and the positioning of the satellites. Typically, a standard GPS module offers an accuracy level within 10 to 15 meters. However, advanced systems utilizing Differential GPS (DGPS) or Real-Time Kinematic (RTK) methods can achieve sub-meter or even centimeter-level accuracy.

GPS modules have a wide range of applications in modern society, serving as essential components in systems used for navigation, timekeeping, tracking, and map-making, among other purposes. Whether integrated into smartphones, cars, or specialized devices, GPS modules facilitate the convenient and precise determination

of geographic positioning, which has become integral to our daily lives. In the following section, we will explore in greater detail the diverse applications and the future advancements of GPS technology (Matan, 2023).

In the JEEP-PS initiative, GPS modules serve as essential components for advancing smart mobility solutions through the implementation of E-Jeepney tracking technology in Nueva Vizcaya. By integrating GPS modules into the e-jeeps, the project aims to enhance the efficiency and reliability of the public transportation system. These modules enable operators to precisely track the location of the E-Jeepneys, providing accurate arrival and departure information to passengers.

The adoption of GPS modules in the JEEP-PS project represents a significant advancement in modernizing and optimizing public transportation services in Nueva Vizcaya. By leveraging the capabilities of GPS technology, the initiative aims to provide residents with reliable, convenient, and sustainable transportation options, ultimately contributing to Nueva Vizcaya's economic development and enhancing the quality of life for its inhabitants.

Alignment to the Sustainable Development Goals and School of Engineering Architecture and Information Technology Research Agenda

The Sustainable Development Goals (SDGs) established by the United Nations in 2015 provide a comprehensive framework for addressing global challenges and promoting sustainability in various dimensions. JEEP-PS, is a Pioneering Smart Mobility Solutions through Advanced E-Jeep Tracking Technology with Arrival and

Departure Information that aligns with several of the Sustainable Development Goals, contributing to creating sustainable cities and establishing partnerships for the goals.

The global positioning system has a direct impact on SDG 11: Sustainable Cities and Communities. JEEP-PS promotes the use of e-jeepneys, which are more eco-friendly forms of transportation while also being a safe, affordable, and sustainable transport system for all. Better coordination of transportation services is made possible by tracking, which also lowers traffic, increases accessibility, and improves the general quality of life in cities. It also enables effective urban planning by offering information and analysis on demand and patterns in transportation, which can help with decision-making regarding the construction of new infrastructure, the improvement of existing routes, and the expansion of public transportation.

As the Philippines is moving towards using a more sustainable public transport system, it addresses problems related to air pollution, traffic congestion, dependence on fuel imports, and carbon emissions, issues that also target SDG 13: Climate Action. When compared to conventional fossil fuel-powered vehicles, e-jeepneys emit fewer or no greenhouse gases because they run on electricity or other clean energy sources. JEEP-PS contributes to the reduction of greenhouse gas emissions from the transportation sector, including carbon dioxide, by encouraging the use of e-jeepneys.

JEEP-PS also aims to involve collaboration between various stakeholders, including government agencies, technology companies, transportation operators, and local communities. By bringing together different actors with complementary

expertise and resources, the platform shows the power of multi-stakeholder partnerships in driving sustainable development initiatives, engaging with SDG 17: Partnership for the Goals.

Additionally, JEEP-PS aligns with emerging trends in the School of Engineering, Architecture, and Information Technology Research Agenda, particularly in the field of Information and Communication Technology (ICT). The integration of IoT (Internet of Things) technology through GPS devices in JEEP-PS enables monitoring and tracking of e-jeepneys, enhancing their operational efficiency, and contributing to data-driven decision-making in transportation management. Furthermore, the development of IT-based applications, programs, and software used in JEEP-PS reflects advancements in software engineering and data analytics, offering innovative solutions for local sustainable urban mobility. As research endeavors in these domains continue to evolve, JEEP-PS stands as a pioneering initiative at the nexus of transportation, sustainability, and technology. It serves as a testament to the transformative potential of leveraging ICT to address pressing urban transportation issues and lays the groundwork for the development of smarter, more environmentally friendly transportation systems.

In the dynamic landscape of transportation, especially in regions like Nueva Vizcaya in the Philippines, the need for innovative solutions that address both environmental concerns, and the efficiency of public transit systems is ever more pressing. The introduction of e-jeepneys, as a sustainable alternative to traditional fossil fuel-powered vehicles, represents a significant step towards achieving these

objectives. However, the successful integration and management of e-jeepneys into the existing transportation infrastructure requires sophisticated technologies and robust management systems. In response to this challenge, the JEEP-PS project emerges as a groundbreaking endeavor, which stands for Pioneering Smart Mobility Solutions through Advanced E-Jeep Tracking Technology with Arrival and Departure Information, aiming to revolutionize the management and operation of e-jeepneys through the implementation of advanced tracking technology and user-centric web application. By harnessing the power of modern technology and fostering collaboration among stakeholders, JEEP-PS seeks to not only improve the efficiency and sustainability of public transportation but also enhance the overall commuting experience for passengers in Nueva Vizcaya and beyond.

With this, JEEP-PS is a web application that features tracking of e-jeeps that makes use of Rapid Application Development. This study aims to cater to the following users:

E-Jeepney Operators. With the help of this study, operators can improve the commuting experience, guaranteeing adherence to service standards, and optimizing their operations with the help of the web app.

Drivers. With this study, drivers can utilize the platform to receive essential notification and updates, ensuring effective performance of their duties and providing timely and reliable transportation services for passengers. The web app offers features that notify drivers about the availability of seats, with a switch to indicate if there are still seats available, helping them manage passenger capacity

efficiently. Additionally, there is a switch to notify people if the transport is under maintenance, ensuring that only in good condition are in use. Furthermore, a service requirement switches alerts operators when the transport needs maintenance, allowing for timely repairs to prevent unexpected breakdowns. In addition, there will be switch to notify the operator and commuters if the E-jeepney is going Northbound or Southbound. The web app provides them with tools and information which are crucial for maintaining high standards of service and operational efficiency in the transportation system.

Commuters. Commuters can access the JEEP-PS web app to track the location and estimated arrival and departure times of e-jeepneys, plan their journeys, and make informed decisions about their transportation options. JEEP-PS is designed to cater to all commuters, ensuring that everyone in Vizcaya will be able to use it effectively.

Future Researchers. This study serves as a repository of data and insights into the operation and management of e-jeepneys within urban transportation systems.

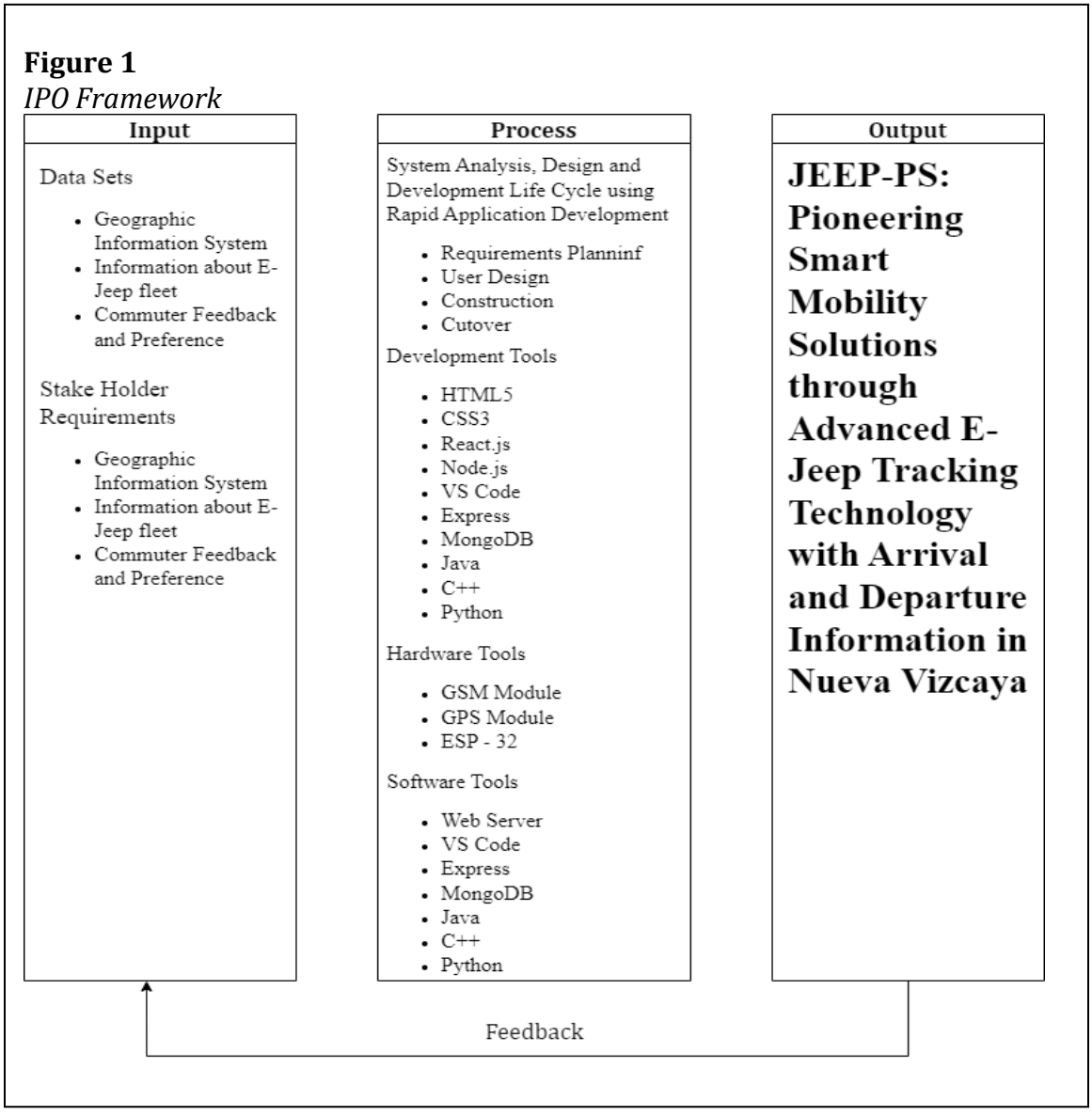
This study is limited to the functionalities for tracking e-jeepneys specifically along the Solano, Bayombong and Bambang routes. The quality and dependability of the data gathered have a major impact on how effective the web application is. The overall dependability of the results may be impacted by errors or gaps in the data caused by restrictions in the data collection techniques or technical problems with

the tracking devices. This study is not affiliated with the Land Transportation Franchising and Regulatory Board, with manufacturers of e-jeepneys.

Conceptual Framework

The study's Input-Process-Output (IPO) model is shown below.

Figure 1
IPO Framework



The figure above serves as a guide in the development of a "Pioneering Smart Mobility Solutions through Advanced E-Jeep Tracking Technology with Arrival and Departure Information in Nueva Vizcaya".

The inputs served as the foundation for the development of the web application, each playing a crucial role in addressing specific aspects of the GPS tracking system. Geographic Information System (GIS) data provides essential geographical context and spatial information necessary for accurate tracking and navigation. This data formed the backbone of the system, enabling efficient route planning and optimization. Additionally, detailed information about the e-jeepney service was incorporated to facilitate effective service management and delivery. Commuter feedback and preferences were carefully considered, informing the integration of user-centric features and functionalities aimed at enhancing the overall commuting experience. By addressing stakeholder requirements, which encompassed both operator needs and commuter expectations, the system was tailored to meet the diverse needs of all involved parties. This holistic approach ensured that the developed GPS tracking system not only met operational objectives but also prioritized user satisfaction and usability by accurately tracking the arrival and departure times of e-jeepneys.

In the process, it is shown that the process follows a systematic approach, adhering to the System Analysis, Design, and Development Life Cycle using Rapid Application Methodology. This RAD framework enables iterative development and

continuous stakeholder engagement, fostering flexibility and responsiveness to evolving requirements. Beginning with requirements planning, the project identifies and prioritizes key functionalities based on stakeholder input. User design focuses on creating intuitive interfaces and user experiences, while construction involves the actual implementation of the system components. The cutover phase marks the transition to the operational environment, ensuring a seamless deployment of the GPS tracking system.

To facilitate development, various tools are employed, including GPS tracking software for monitoring and location tracking. Geographic Information System (GIS) tools are utilized for spatial data analysis and visualization, enhancing route planning and optimization. RAD project management tools such as JIRA and Trello facilitate collaboration, task management, and progress tracking throughout the development lifecycle. These development tools, combined with a systematic approach and stakeholder-driven requirements, contribute to the successful creation and deployment of the GPS tracking system for e-jeepneys in Nueva Vizcaya.

Statement of the Problem (or Objectives)

The e-jeep tracking system that is part of the overall transport network in Nueva Vizcaya has its challenges that affect the commuter's safety, efficiency, and convenience.

This study aims to provide answers to the following queries:

1. What are the difficulties that e-jeep operators face in terms of:
    1.1. Passenger management?
2. What are the main problems commuters experience when trying to catch up with reliable and timely transportation in terms of:
    2.1. Availability, and
    2.2. Clarity of routes and schedule?
3. What system will be developed to solve the problems encountered by e-jeep operators and commuters in Nueva Vizcaya?
4. What is the extent of compliance of the proposed "JEEP-PS: Pioneering Smart Mobility Solutions through Advanced E-Jeep Tracking Technology with Arrival and Departure Information in Nueva Vizcaya" with ISO 25010:2015 Software Quality Standards as assessed by commuters, operators, and regularly authorities in terms of:
    4.1. Functional Suitability,
    4.2. Performance Efficiency,
    4.3. Compatibility,
    4.4. Usability,
    4.5. Reliability,
    4.6. Security,
    4.7. Maintainability, and
    4.8. Portability?

CHAPTER 2
METHODOLOGY

Research Design

To ensure the effectiveness of the study, a combination of descriptive and developmental research methodologies will be employed, considering the dual focus on both software and hardware development.

In the descriptive research design phase, interviews and small group discussions will be conducted to gather the necessary data. These methods will facilitate the exploration of key factors such as route planning challenges, passenger management issues, availability of transportation services, and clarity of routes and schedules. By directly engaging with e-jeep operators, drivers, and commuters in Nueva Vizcaya, the study aims to identify specific requirements and constraints that must be addressed in the development of the JEEP-PS system.

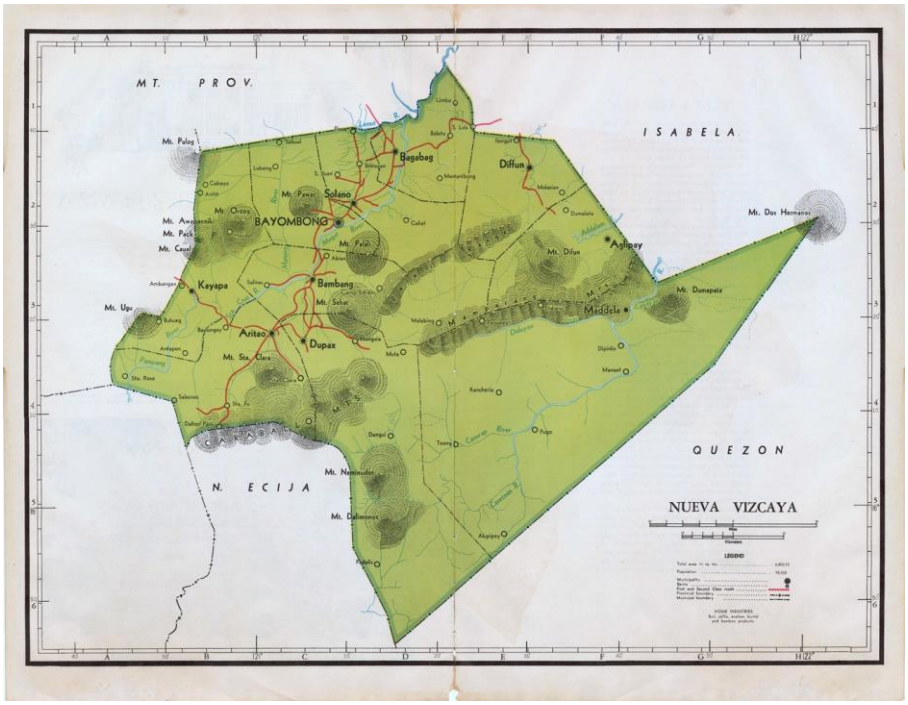
For the developmental phase, the Rapid Application Development (RAD) methodology will be adopted for software development. RAD facilitates iterative design, prototyping, and implementation of the software application, aligning with the dynamic nature of the project. This approach supports rapid prototyping and user involvement, enabling the development team to quickly iterate on design ideas and incorporate feedback from stakeholders. Additionally, RAD allows for flexibility and adaptability to evolving requirements, ensuring that the final product meets the identified needs and expectations of stakeholders.

In parallel, the hardware development will follow the Spiral Model, a flexible and iterative approach tailored to address the intricate challenges inherent in hardware design and prototyping. The Spiral Model offers a structured framework that acknowledges the dynamic nature of hardware development, allowing for continuous refinement and adaptation throughout the project lifecycle. It enables the development team to navigate complexities, uncertainties, and risks inherent in hardware design, ensuring the delivery of robust and reliable components.

The study will commence by gathering and analyzing information through in-person interviews to determine project requirements. Subsequently, the researcher will design the system based on the insights gained from these interviews, with a focus on integrating both software and hardware components seamlessly. This iterative approach, guided by descriptive and developmental research methodologies, aims to deliver a holistic solution that enhances the efficiency and effectiveness of e-jeep transportation in Nueva Vizcaya.

Research Locale

Figure 2
Nueva Vizcaya Map



Source: https://images.app.goo.gl/XkU1y6dAAPVuXFrVA

The prototyping phase will take place in Nueva Vizcaya, a province in the Philippines. Nueva Vizcaya has been identified for this purpose due to its robust transportation infrastructure, particularly its widespread deployment of e-jeepneys, which serve as a primary mode of transportation for a significant portion of the local population.

With this, the endeavor extends beyond mere technological innovation. It aspires to catalyze a paradigm shift in transportation systems across similar regions. By leveraging the unique characteristics of Nueva Vizcaya, the aim is to not only

optimize mobility solutions within the province but also pave the way for scalable and adaptable models that can be implemented in diverse contexts. Through collaborative efforts with local stakeholders and the integration of cutting-edge technologies, this study endeavors to redefine the standards of smart mobility, fostering sustainable development and improving quality of life for communities far beyond its immediate locale.

Research Participants

The functionalities and success of "Pioneering Smart Mobility Solutions through Advanced E-Jeep Tracking Technology with Arrival and Departure Information in Nueva Vizcaya" can only be realized and achieved with the participation of the users.

Drivers. These individuals are responsible for operating the E-Jeeps, ensuring safe and efficient transportation for commuters.

Operators. Operators oversee the operation of the E-Jeeps. This may include cooperative members who manage the fleet and coordinate routes and schedules.

Commuters. Commuters are the primary users of the E-Jeep service. They rely on it for transportation to their destinations and provide feedback on their experience.

Admin. They handle system configurations, user management, and overall maintenance to ensure smooth operation.

Research Instruments

To gather essential data and insights necessary for the development and implementation of the JEEP-PS prototype, interviews and document reviews will be conducted.

Interview

Interviews will be conducted with key stakeholders, including E-jeepney operators and drivers, to explore their operational procedures, challenges, and requirements. The interview guide, developed based on project objectives, will consist of open-ended and closed-ended questions designed to elicit detailed responses and specific data points.

For E-jeepney Operators and Drivers:

1. What are the main challenges you face in operating E-jeepneys in Nueva Vizcaya?

2. How do you currently manage route schedules and passenger pickups/drop-offs?

3. What improvements do you think can be made to enhance the efficiency of E-jeepney operations?

4. On a scale of 1 to 5, how satisfied are you with the current transportation management system? (1 being very dissatisfied, 5 being very satisfied)

5. What features or functionalities would you like to see in a new E-jeepney tracking system?

Document Reviews

Document reviews will involve examining various documents related to the transportation system in Nueva Vizcaya, including regulations, policies, and reports. These documents will provide valuable background information and context for the project. The information extracted from these reviews will be synthesized to identify key considerations for the development of the JEEP-PS prototype.

For Document Reviews:

1. What are the main regulatory requirements governing public transportation in Nueva Vizcaya?

2. Are there any existing policies or initiatives aimed at improving transportation efficiency and passenger safety?

3. What insights can be gathered from previous reports or studies related to E-jeepney operations in the region?

4. How do existing transportation regulations align with the goals of the JEEP-PS project?

5. What are the main challenges identified in previous documents that need to be addressed by the JEEP-PS application?

Overall, the combination of interviews and document reviews will provide a robust foundation of data and insights to inform the development of the JEEP-PS prototype, ensuring its relevance and effectiveness in addressing the needs of stakeholders in Nueva Vizcaya.

Data Gathering Procedure

The data-gathering process for the JEEP-PS prototype will be meticulously planned and executed to ensure the collection of comprehensive and relevant information necessary for its development and implementation.

Interviews will be conducted with key stakeholders, including e-jeepney operators, drivers, local transportation authorities, and relevant government agencies. These interviews will aim to delve into various aspects of the transportation system in Nueva Vizcaya, including operational procedures, challenges, and requirements. The interview guide, meticulously crafted based on the project's objectives, will consist of a blend of open-ended and close-ended questions designed to elicit detailed responses and specific data points. Prior to each interview session, explicit permission will be obtained through informed consent forms, emphasizing confidentiality assurances and the research objectives.

In parallel with interviews, extensive research will be conducted on the local transportation industry. This research will involve analyzing regulations, policies, and reports related to public transportation in Nueva Vizcaya. By examining these documents, valuable insights will be gained into the regulatory framework, existing policies, and previous studies or reports relevant to e-jeepney operations in the region. The information extracted from document reviews will provide additional context and enrich the understanding of the transportation landscape, complementing the insights gathered from interviews.

Ultimately, a thorough analysis of the gathered data will be conducted to extract actionable insights and inform the development of the JEEP-PS prototype. This analysis will involve synthesizing information from interviews, research findings, and document reviews to identify key considerations and requirements for the prototype. By systematically analyzing the data, the research team will be able to shape the design and functionality of the JEEP-PS prototype to effectively address the identified needs and preferences of stakeholders in Nueva Vizcaya.

Through this structured and ethical approach to data gathering, the research aims to uphold the integrity of the research process and ensure that the resulting prototype truly meets the requirements of the local transportation ecosystem in Nueva Vizcaya.

Treatment of Data

The data that were gathered from the research instruments were used as the basis for the creation of the software architecture of the application. In the treatment of data, the researcher transcribed the data with confidentiality because the data contained sensitive information from the respondents. The collected data was organized by the researcher for simple analysis. The researcher began by organizing the data in order of significance for addressing the statement of the problem.

After gathering the requirements and preferences through interviews and document reviews, prototypes were created and presented to the pilot organization of the application. Comments and suggestions were gathered and applied to the next iteration of the application. If there were no more future recommendations,

suggestions, and corrections on the flow, user interface, information management, data logic, and system logic of the application, the developed application was considered as good as finished and ready for use.

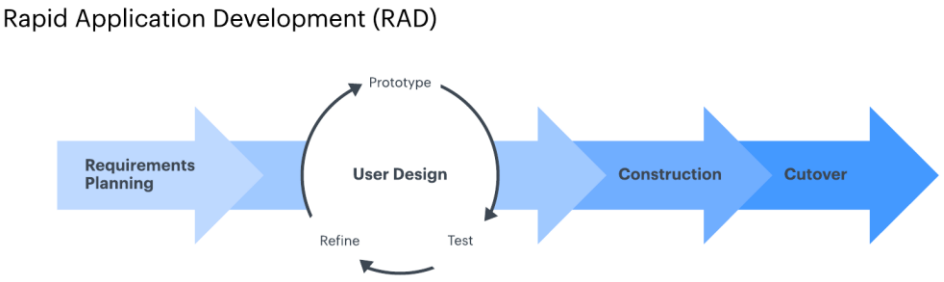
For the system evaluation, ISO 25010:2015 Software Quality Standards was used by the different users of the system. The descriptive statistical tools used in the study were frequency, percentage, and mean. The weighted mean was used to determine the extent of compliance of the application with ISO 25010:2015 Software Quality Standards. The extent of compliance of the application was rated using the following Likert scale:

Table 1
Measurement of the Extent of Compliance with ISO 25010:2015 Software Quality Standards

Mean Range	Descriptive Equivalent	Interpretation
4.20 – 5.00	Compliant to the very great extent	The measure described in the item is compliant to the very great extent or OUTSTANDING.
3.40 – 4.19	Compliant to a great extent	The measure described in the item is compliant to a great extent or VERY SATISFACTORY.
2.60 – 3.39	Compliant to a moderate extent	The measure described in the item is compliant to a moderate extent or SATISFACTORY.
1.80 – 2.59	Compliant to a little extent	The measure described in the item is compliant to a little extent or FAIR.
1.00 – 1.79	Compliant to the very little extent	The measure described in the item is compliant to a very little extent or POOR.

Software Development

Figure 3
Rapid Application Development (RAD)



Source: https://www.researchgate.net/publication/346578678_ASIAVR_Asian_Studies_Virtual_Reality_Game_a_Learning_Tool

The adoption of Rapid Application (RAD) is a practical approach for the development of JEEP-PS, Pioneering Smart Mobility Solutions through Advanced E-Jeep Tracking Technology with Arrival and Departure Information in Nueva Vizcaya. This methodology represents a lifecycle strategy offering expedited and superior-quality outcomes in contrast to conventional cycles. RAD stands as a software development method embracing an object-oriented approach to system development (Sasmito et al., 2020).

The RAD methodology provides an opportunity for individuals with varying levels of expertise to harness the power of high-performance computing. This enables swift prototyping, retargeting, and repurposing of existing software, rendering it an ideal framework for JEEP-PS development (Nalendra, 2021). This method suits JEEP-PS well by allowing for ongoing evaluation and enhancement, ensuring user satisfaction. The RAD methodology in software development prioritizes rapid

prototyping and iterative development to efficiently meet project requirements. Its core aim is to minimize development time and costs by promptly delivering a functional prototype for client feedback and refinement. RAD fosters close collaboration between developers and stakeholders throughout requirement identification, design, prototyping, development, and testing. It incorporates client feedback iteratively to refine the prototype until the final product is achieved. This approach is particularly beneficial for projects with evolving requirements and tight deadlines, ensuring swift time-to-market (Sandler, 2023).

The following are the phases of RAD that are undertaken:

Requirement Planning

To ensure that the development of the JEEP-PS application meets the specific needs of the transportation industry in Nueva Vizcaya, a series of interviews will be undertaken with key stakeholders. These interviews will include discussions with e-jeepney operators to understand fleet management procedures and optimize service standards. Insights gained from these discussions will be instrumental in refining the application's features to align with operator requirements and enhance operational efficiency.

Additionally, interviews will be conducted with e-jeepney drivers to gather insights into their daily routines, route preferences, and communication needs. By understanding drivers' perspectives, the research team will be able to tailor the application to provide essential route information, navigation support, and real-time updates on passenger pickups and drop-offs. This will ensure that drivers can

perform their duties effectively, resulting in improved service reliability for commuters.

User Design

This phase will involve the creation of the initial application design based on the requirements identified in the analysis stage, followed by the development of prototypes, user testing, and iterative refinement to ensure optimal usability and functionality.

The design phase will begin with the creation of the initial application design, which will be based on the requirements and features identified during the Requirements Planning stage. Emphasis will be placed on understanding the specific needs and preferences of e-jeep operators and commuters to ensure that the application design effectively addresses their challenges and improves their overall experience.

Following the initial design phase, the researcher will proceed to develop a prototype of the JEEP-PS application. The prototype will aim to provide a visual representation of the application's interface and functionalities, allowing stakeholders to interact with the system and provide feedback. This prototype will serve as a preliminary version of the application, enabling stakeholders to visualize the proposed solution and identify any potential issues or areas for improvement.

Once the prototype is developed, it will be subjected to user testing by pilot users, including e-jeep operators, drivers, and commuters. These pilot users will be selected to represent the target audience of the application and provide valuable

insights into its usability and functionality. During the user testing phase, pilot users will be asked to perform various tasks within the application while providing feedback on their experience, usability, and any issues encountered.

Based on the feedback received from pilot users during the user testing phase, the researcher will proceed to refine the application's features and functionalities iteratively. This iterative refinement process will involve identifying and addressing any usability issues, bugs, or inconsistencies within the application to improve its overall performance and user experience. Additionally, risks and problems associated with the user design will be identified and addressed to ensure the functionality and usability of the application.

Throughout the User Design phase, collaboration between the researcher and the users will be essential to ensure that the application design meets the users' requirements and preferences effectively. Stakeholder feedback will be actively sought and incorporated into the design process to create a product that satisfies the diverse needs of e-jeep operators and commuters in Nueva Vizcaya.

Construction Phase

The construction phase will mark the pivotal stage in the development of the JEEP-PS application, where the conceptual designs and prototypes will transition into a fully functional system. This phase will involve the implementation of the application design created in the previous stages, requiring close collaboration between the researcher, clients, and end-users to ensure alignment with the project objectives and expectations established during the analysis and design phases.

The interpretation of prototypes will serve as a guiding light in the development process. Insights gained from user feedback during the prototype testing phase will inform the development team's decisions as they translate the conceptual designs into tangible features and functionalities. By leveraging the feedback gathered from clients and users, the development team will refine the application's design and functionality to ensure it meets the evolving needs of its stakeholders.

The development process will follow an iterative approach, where each component and feature of the application will undergo individual development and testing. This iterative nature will allow for rapid identification and resolution of any issues or inconsistencies, ensuring the delivery of a functional and efficient application. Through a structured cycle of planning, coding, testing, tweaking, and debugging, the development team will maintain a fast-paced and reasonable cadence, driving the project forward towards its completion.

Effective communication between the researcher, clients, and users will be paramount during the construction phase. Regular updates and progress reports will ensure that all stakeholders are informed of the project's status and any emerging issues are addressed promptly. This open line of communication will foster collaboration and enable the development team to incorporate feedback in real-time, ensuring that the final product aligns with the expectations and needs of its intended users.

Documentation and version control will play a crucial role in maintaining the project's organization and efficiency during the development stage. Comprehensive documentation of the development process, including coding standards, system architecture, and user manuals, will ensure that the project remains transparent and accessible to all stakeholders. Version control mechanisms will track changes made to the application codebase, facilitating collaboration among team members, and ensuring the integrity of the software development process.

Overall, the construction phase will represent a critical step in the creation of the JEEP-PS application. The collaborative efforts between the researcher, clients, and users, combined with iterative development practices and effective communication, will ensure the functionality and usability of the application align with the project's objectives and expectations.

Cutover Phase

The cutover phase will represent the culmination of the development process, involving the implementation of the designed JEEP-PS prototype for the pilot client, with their consent. This phase will be characterized by meticulous planning and execution to ensure a smooth transition from development to deployment, accompanied by the establishment of maintenance protocols to uphold the application's functionality and usability post-deployment.

Central to the cutover phase will be the creation of an implementation plan, detailing the scheduled activities between the researcher and the client to initiate deployment and user training for e-jeep operators and commuters in Nueva Vizcaya.

This plan will outline the systematic rollout of the application, ensuring that all stakeholders are adequately prepared for its introduction into the operational environment.

The application will undergo rigorous pilot testing during this phase, involving selected e-jeep operators, drivers, and commuters who represent the target audience. These pilot users will engage with the application in real-world scenarios, providing valuable feedback on its usability, functionality, and performance. Any issues identified during this phase will be promptly addressed to ensure that the application meets the users' needs and operates effectively in practical settings.

A comprehensive maintenance plan will be established to safeguard the application's continued functionality and usability following its deployment. This plan will include oversight by the researcher to monitor the transition process and address any bugs or errors that may arise during initial use. The development team will remain proactive in resolving issues to ensure the application's sustained usability and functionality over time.

Effective communication between the development team, the pilot client, and the users will be paramount during the cutover phase. This will ensure that any issues or feedback are addressed promptly, fostering a collaborative environment focused on achieving user satisfaction. Additionally, documentation and version control will be upheld to maintain project organization and efficiency, facilitating ongoing support and development efforts.

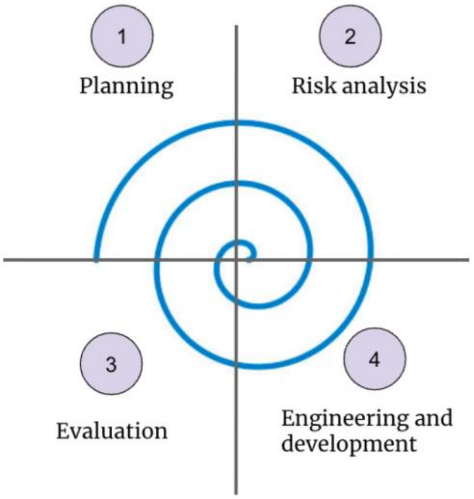
The cutover phase will serve as a pivotal step in the development of the JEEP-PS prototype, marking its successful implementation and transition into operational use. Through meticulous planning, rigorous testing, and proactive maintenance, the application will be poised to meet the needs of its users effectively, resulting in improved mobility solutions and enhanced user satisfaction in Nueva Vizcaya.

Hardware Development

The development of hardware components for the JEEP-PS project adopts the Spiral Model, a flexible and iterative approach tailored to address the intricate challenges inherent in hardware design and prototyping.

The spiral model integrates aspects of both design and prototyping across stages to merge the benefits of top-down and bottom-up approaches (Alshamrani, 2019). It offers a structured framework that acknowledges the dynamic nature of hardware development, allowing for continuous refinement and adaptation throughout the project lifecycle. It enables the development team to navigate complexities, uncertainties, and risks inherent in hardware design, ensuring the delivery of robust and reliable components.

Figure 4
Spiral Model



4 phases of the spiral model

Source: https://blog.logrocket.com/product-management/risk-driven-development-with-the-spiral-model/

The following are the phases of the Spiral Model that are undertaken:

Planning

To initiate the hardware development process for the JEEP-PS project, meticulous planning will serve as the foundational phase to ensure clarity, alignment, and effective resource utilization. Key stakeholders, including project managers, engineers, and end-users, will collaborate to define clear objectives, scope, and deliverables. Through comprehensive discussions and analysis, the specific goals of the hardware components will be articulated, ensuring alignment with project objectives.

Moreover, the planning phase will involve a rigorous examination of potential alternatives and constraints that may impact the development process. The development team will explore various design options, technologies, and methodologies to determine the most suitable approach. Factors such as performance requirements, cost-effectiveness, and scalability will be carefully evaluated to identify optimal solutions.

Furthermore, resource requirements, including personnel, materials, and equipment, will be meticulously assessed to ensure adequate allocation and utilization. Budget constraints and financial considerations will be considered to maintain alignment with project budgets. Additionally, technological feasibility will be scrutinized to assess the viability of leveraging existing technologies or developing custom solutions.

In parallel, risk assessment and mitigation strategies will be formulated to address potential challenges and uncertainties. Through thorough analysis and planning, the development team will lay the groundwork for subsequent phases of development, ensuring a structured and strategic approach to hardware design and prototyping.

Risk Analysis

During the Risk Analysis phase of the hardware development process for the JEEP-PS project, the development team will delve into a comprehensive examination of potential risks and challenges that may impact the project's success. This phase will

be crucial for identifying, evaluating, and mitigating uncertainties to ensure smooth progress throughout the development lifecycle.

Firstly, the development team will explore various design alternatives, considering different approaches, technologies, and methodologies to achieve the project objectives. Each alternative will be carefully evaluated based on factors such as feasibility, scalability, and alignment with project requirements. Through this exploration process, the team aims to identify the most viable design options that offer optimal performance and efficiency.

Simultaneously, rigorous risk analysis will be conducted to anticipate and mitigate potential challenges that could arise during hardware development. The development team will systematically assess various aspects, including technical, operational, and external factors, to identify potential risks and their potential impact on project timelines, costs, and outcomes.

Risk identification will involve proactive brainstorming sessions, consultations with subject matter experts, and analysis of historical data to uncover potential threats and vulnerabilities. These risks may encompass issues such as technical complexities, resource constraints, regulatory compliance, supply chain disruptions, and unexpected changes in project scope or requirements.

Once risks are identified, they will be carefully evaluated based on their likelihood of occurrence and potential impact on project objectives. Risks will be prioritized based on their severity and the level of impact they could have on the

project. This prioritization will allow the development team to focus their attention and resources on addressing the most critical risks first.

Following risk assessment, mitigation strategies will be developed to minimize the likelihood and impact of identified risks. These strategies may include contingency plans, alternative approaches, risk transfer mechanisms, and preventive measures aimed at reducing the probability of risk occurrence. The development team will collaborate closely to implement these mitigation strategies effectively, ensuring proactive risk management throughout the hardware development process.

By conducting a thorough risk analysis and implementing appropriate mitigation strategies, the development team will lay the groundwork for a resilient and adaptive approach to hardware development. This proactive approach will help mitigate uncertainties, enhance project resilience, and facilitate smooth progress towards achieving project objectives within the Spiral Model framework.

Engineering and Development

During the Engineering and Development phase, the focus shifts to iterative testing and refinement, with the goal of validating the functionality, performance, and reliability of the hardware components.

The development team initiates this phase by translating the conceptual designs outlined in the planning phase into tangible prototypes. Utilizing tools and technologies such as the ESP-32 microcontroller, GPS module, and GSM module, the team constructs physical representations of the hardware components. These

prototypes serve as initial versions of the hardware, enabling the team to assess their functionality and detect any design flaws or performance issues.

Following the construction of prototypes, comprehensive testing is conducted to evaluate their performance and reliability. This testing encompasses various methodologies, including functional testing, stress testing, and compatibility testing. Functional testing verifies whether the hardware components meet specified requirements and execute intended functions effectively. Stress testing examines the hardware's performance under extreme conditions or heavy workloads to pinpoint potential weaknesses or vulnerabilities. Compatibility testing ensures seamless integration of the hardware components with other systems or devices, such as software applications or communication networks.

Throughout the testing process, the development team gathers data and feedback to pinpoint areas for improvement and optimization. Issues and deficiencies are documented, prompting iterative changes to the hardware designs. This iterative approach will enable the team to refine the prototypes, optimize performance, enhance reliability, ensuring alignment with project requirements and user expectations.

In addition to functional and performance testing, the reliability and durability of the hardware components are evaluated. Reliability testing gauges the hardware's consistency over time and under diverse conditions, while durability testing assesses its resilience to environmental factors, physical stress, and wear and tear. By subjecting prototypes to rigorous testing, the team identifies potential weaknesses or

failure points, enabling adjustments to enhance the hardware's robustness and longevity.

Overall, the Engineering and Development phase represents a critical stage in the hardware development process. Here, prototypes are meticulously created, tested, and refined to ensure functionality, performance, and reliability. Through iterative testing and optimization, the development team can progressively enhance the hardware designs, addressing issues and optimizing performance to meet project requirements and user needs.

Evaluation

During the Evaluation phase, the development team conducts a comprehensive review of the progress achieved during the Engineering and Development phase and identifies opportunities for improvement and refinement.

Data and feedback collected from various testing activities, including functional testing, stress testing, compatibility testing, reliability testing, and durability testing, are carefully analyzed. Performance metrics and key performance indicators are assessed to gauge whether the hardware components meet specified requirements and performance targets. Any issues, deficiencies, or shortcomings discovered during testing are documented and prioritized based on their severity and impact on project objectives.

Based on the evaluation findings, the development team collaborates to plan the next iteration of hardware development. This entails identifying areas for improvement, defining action items, and setting goals and objectives for the

upcoming phase of development. Insights gleaned from testing outcomes, stakeholder feedback, and emerging technological trends inform decision-making and guide prioritization efforts.

Iterative planning enables the team to integrate lessons learned from testing and feedback into the hardware design and development process. This iterative approach fosters continuous improvement and refinement, ensuring that the hardware components evolve to meet the changing needs of the project. By embracing feedback-driven development, the team can address issues, optimize performance, and enhance reliability, ultimately delivering a high-quality product that aligns with project requirements and user expectations.

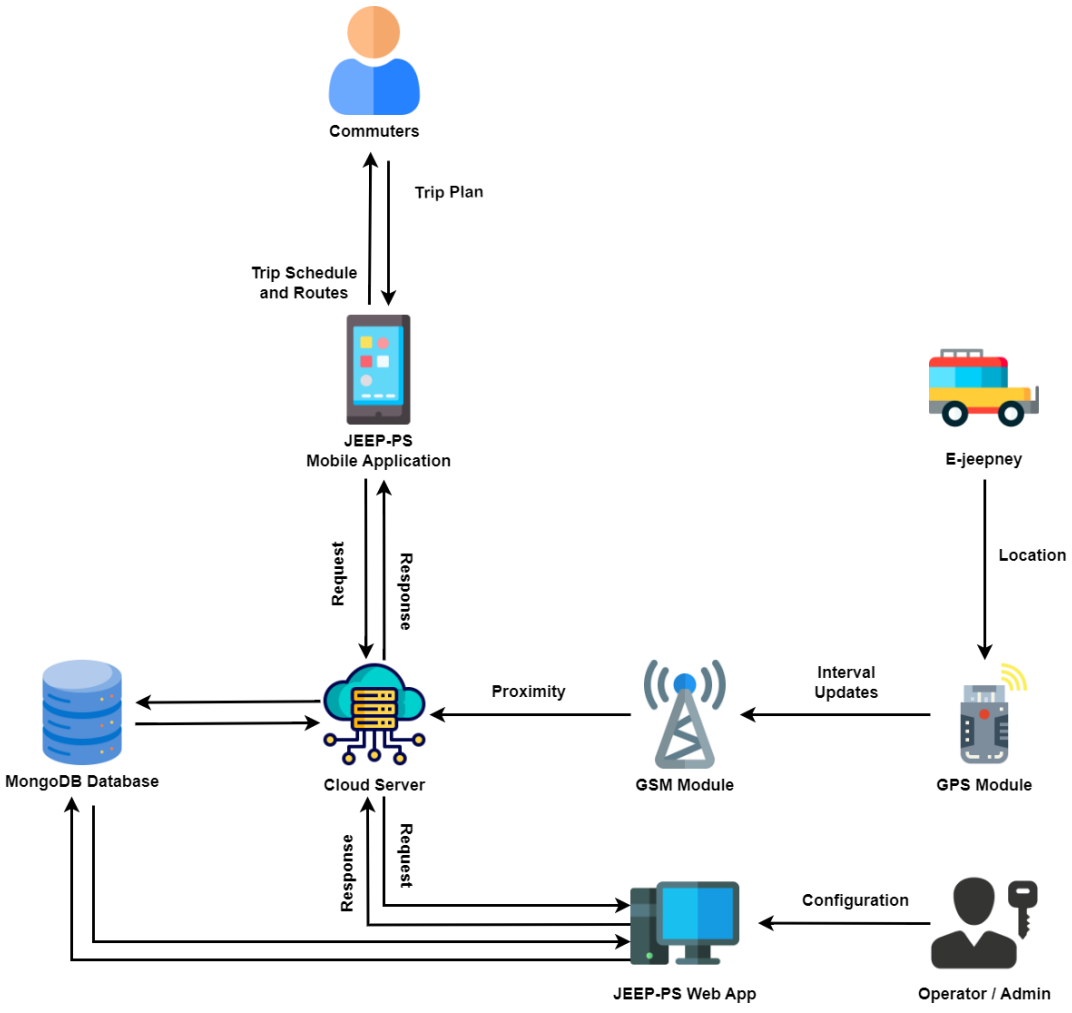
Furthermore, the Evaluation phase provides an opportunity for the development team to reassess project timelines, resource allocations, and budgetary constraints. Adjustments may be made to project plans based on evaluation findings, ensuring that the project remains on course and aligned with its goals and objectives. Clear communication and collaboration among team members are crucial during this phase to ensure alignment and commitment to the next steps in the development process.

Overall, the Evaluation phase represents a critical juncture in the hardware development lifecycle. Here, the development team evaluates progress, identifies improvement areas, and charts the course for the next phase of development. By embracing an iterative approach and leveraging insights gained from testing and

feedback, the team can drive continuous improvement and ensure that the hardware components evolve to meet the evolving needs of the project.

System Architecture

Figure 5
System Architecture



The System Architecture of the JEEP-PS project is designed to provide prompt and location-aware information to commuters, administrators, operators, and drivers. A cloud-based infrastructure is the core of the architecture, it will facilitate data storage, retrieval, and application hosting. The JEEP-PS Web Application serves as the primary interface for users, offering essential functionalities such as route information, schedule updates, and proximity alerts.

Commuters will access the JEEP-PS Web Application via smartphones or computers to obtain relevant information about E-Jeepney routes and schedules. The web application then utilizes a proximity-based notification system to alert commuters about the estimated distance of approaching E-Jeepneys from their designated stops. This notification system will rely on pre-defined route data stored in the MongoDB database, which includes estimated travel times and distances between waypoints along the routes.

Meanwhile, drivers will be equipped with GPS modules installed in E-Jeepneys to provide approximate location data. These GPS modules communicate with the GSM modules to transmit location updates at predefined intervals, rather than in real-time. The location data is then periodically sent to the Cloud Server, where it will be processed to determine the proximity of E-Jeepneys to designated stops along their routes. This processed information is then made available to commuters through the web application's proximity alerts.

Administrators and operators will interact with the JEEP-PS Web Application through computers to manage system configurations, updates, and performance monitoring. The web application will communicate with the Cloud Server to retrieve and update data related to route configurations, schedule changes, and operational parameters. This communication will ensure that administrators and operators have access to up-to-date information to effectively manage the E-Jeepney transportation system.

In summary, the System Architecture of the JEEP-PS project will adopt a proximity-based approach to provide timely information to users without the need for real-time tracking. By using a cloud-based infrastructure and location-aware notification system, the architecture will enable efficient data management and dissemination, enhancing the overall efficiency and effectiveness of E-Jeepney transportation in Nueva Vizcaya.

Development Tools

The researcher used a variety of tools to fully create the web application. Here's a breakdown of each tool and what it was used for:

HTML5

This is like the skeleton of a webpage. It's a simple language used to structure the content you see on the internet.

CSS3

CSS stands for Cascading Style Sheets. It's used to make websites look pretty by changing things like colors, fonts, and layout.

React.js

This is a tool for building the parts of the webpage that users interact with, like buttons and forms. It's especially good for making single-page applications that feel smooth and responsive.

Node.js

Node.js is used to run JavaScript code outside of a web browser. It's great for building the behind-the-scenes part of websites, like managing data and handling user requests.

Visual Studio Code

This is a handy tool for writing and editing code. It helps developers catch mistakes, run tasks, and manage their projects more efficiently.

Express

Express is a framework for building web applications with Node.js. It provides a bunch of helpful features for creating both web and mobile apps.

Hostinger

This is a web hosting provider that was used to make the application accessible online, so people can use it from anywhere.

MongoDB

MongoDB is a type of database used to store all the data for the application. It's good for handling lots of different types of information and scaling up as the application grows.

Java

It excels in server-side programming, handling tasks like data processing and business logic implementation.

ESP-32

The ESP-32 stands as a multifaceted microcontroller frequently employed in IoT endeavors, showcasing capabilities to connect to Wi-Fi networks, thus serving as an optimal choice for crafting internet-connected devices.

GPS Module

A GPS module serves as a hardware component tasked with receiving signals from satellites to ascertain the geographical coordinates of a device. Its prevalent use extends to projects necessitating location tracking, such as vehicle navigation systems or asset monitoring applications.

Web Server

A web server is a kind of software that serves web pages to clients over the internet. It processes incoming requests from web browsers and delivers the appropriate content, making it possible to host and serve web applications.

GSM Module

A GSM module allows devices to connect to mobile networks, enabling communications via SMS, voice calls, or data transmission. It's useful for IoT projects that require remote monitoring or control capabilities.

C++

C++ is a powerful programming language commonly used for system programming, game development, and performance-critical applications. It's well-suited for projects that require low-level control or high performance.

Python

Python is a versatile programming language known for its simplicity and readability. It's widely used in web development, data analysis, artificial intelligence, and automation tasks. Python's extensive library ecosystem makes it a popular choice for a wide range of applications.

Software Requirements

Table 2
Software Requirements

Number	Software	Purpose
1	Visual Studio	One need for creating the JEEP-PS website application to build and design the user interface of the website and application.
2	Browser (Google Chrome, Microsoft Edge, Mozilla Firefox, Internet Explorer, etc.)	To access the JEEP-PS web app online, the user must have this.

Source: *(if taken from a different material)*

Hardware Requirements

Table 3
Hardware Requirements

Number	Hardware	Purpose
1	Android Phone	To access the JEEP-PS website and run the JEEP-PS application.
2	Desktop/Laptop	To access the JEEP-PS website and to locate the E-jeepneys.
3	GPS Module	To determine the geographical position of E-jeepneys
4	GSM Module	To communicate and transmit data in the JEEP-PS system
5	ESP - 32	To enable data exchange, system coordination, and potential onboard processing

Source: *(if taken from a different material)*

Ethical Consideration

This study will be submitted to the Research Ethics Board (SMUREB) at Saint Mary's University for ethics review, located the 2nd Floor, Rev. John Van Bauwel Hall, SMU Main Campus, Ponce Street, Don Mariano Marcos; Bayombong, 3700 Nueva Vizcaya, Philippines (email: reb@smu.edu.ph;cellphone: 09177053041).

Conflict of Interest

There was no personal gain or benefit to others because of conducting this study which could compromise the integrity of the results.

Confidentiality and Data and Privacy Protection

The confidentiality and protection of data and privacy were paramount in this study, with the integration of non-disclosure agreements (NDAs) to safeguard vital information. The information collected during this study will be treated with the utmost confidentiality. To ensure the anonymity of individuals, no identifying details will be incorporated into the study's findings or subsequent publications.

All research data will be meticulously stored in secured, locked files, bolstered by the implementation of NDAs. Access to these files will be strictly limited to the researchers. Additionally, access to personally identifiable information will be granted only to those individuals with a legitimate need, and this access will be confined to the specific information required for examination.

In instances where respondents responded positively and agreed to participate in the research project, an additional layer of security will be established through the use of NDAs. Respondents will be supplied with the necessary information, and they will be requested to provide truthful and honest responses, completing the required components of the study.

The integration of NDAs, alongside robust data protection measures, exemplifies the researcher's commitment to maintaining the confidentiality and privacy of all involved parties while ensuring the integrity of the research process.

Management of Vulnerability

The respondents of the study do not belong to a vulnerable group since they are all legal age. The researchers contacted them directly and they were not coerced into participating in the study.

Risk/Benefit Ratio

There will be no risk in the participation of the participants in the study. On the other hand, they will contribute to the development of the application because of this study.

Informed Consent

Before proceeding with the interviews, the participant's permission will be obtained. Consent forms will be asked to be completed before data gathering. Those who would agree to participate will be provided with all the information that will be gathered by the researcher. The participants in the study would also be given access to the results of the study.

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Appendix A Student Researcher's Letter of Intent for Prospective Adviser-Promoter

SAINT MARY'S UNIVERSITY
BAYOMBONG, NUEVA VIZCAYA, PHILIPPINES
UNIVERSITY RESEARCH CENTER

Document Code	URC-FO-010
Revision	02
Effectivity Date	2022/11/17
Page/s	Page 1 of 1

STUDENT-RESEARCHERS' LETTER OF INTENT
FOR PROSPECTIVE ADVISER-PROMOTER

March 12, 2024

ENGR. CARINA S. MALLILLIN
Officer-In-Charge, Office of the Dean
School of Engineering, Architecture and Information Technology

Dear Madam:

We, the undersigned, wish to avail of the services of ENGR. TEOFILO M. SAGABAEN as adviser to our research paper entitled FEED-FU: PIONEERING SMART MOBILITY SOLUTIONS THROUGH ADVANCED E-JEEP TRACKING TECHNOLOGY WITH ARRIVAL AND DEPARTURE INFORMATION IN BAYOMBONG

We promise to work closely with our adviser-promoter in the accomplishment of our project and to comply with the deadlines set by him / her, as well as make ourselves available for consultation to facilitate the research process.

Proponents (*Names and Signatures*):

RAYNE ANGELICA O. NAVAL
LIEZEL MAE P. ARAOS
NOEMI SHANE R. PUYALES
RAIZEL JOY V. LAPADA

Recommending Approval:

MS. ROCEL AUDREY J. BATARA
Research Instructor
(Signature over Printed Name)

Appendix B Adviser-Promoter Acceptance Form

SAINT MARY'S UNIVERSITY
BAYOMBONG, NUEVA VIZCAYA, PHILIPPINES
UNIVERSITY RESEARCH CENTER

Document Code	URC-FO-011
Revision	02
Effectivity Date	2022/11/17
Page/s	Page 1 of 1

ADVISER-PROMOTER ACCEPTANCE FORM

March 12, 2024

☑ I hereby accept the proponent/s:

1. RAYNE ANGELICA O. NAVAL
2. LIEZEL MAE P. ARAOS
3. RAIZEL JOY E. LAPADA
4. NOEMI SHANE R. PUYALES
5. _____

as research advisee/s for the study,

JEEP-PS: PIONEERING SMART MOBILITY SOLUTIONS THROUGH ADVANCED E-JEEP TRACKING TECHNOLOGY WITH ARRIVAL AND DEPARTURE INFORMATION IN BAYOMBONG

for the School Year 2023-2024-SEM 2 to 2024-2025 SEM 1

I promise to abide by my duties and responsibilities and ascertain that my advisees finish their research output on schedule and according to the rules set by the University Research and Community Development Council.

Conforme:

TEOFILO M. SAGABAEN
Printed Name and Signature of Prospective Adviser-promoter

☐ I cannot accept the above thesis advisership due to the following reasons:

_____

_____

_____
Printed Name and Signature of Requested Adviser-promoter

Appendix C Agreement on Promotership

SAINT MARY'S UNIVERSITY
BAYOMBONG, NUEVA VIZCAYA, PHILIPPINES
UNIVERSITY RESEARCH CENTER

Document Code	URC-FO-012
Revision	02
Effectivity Date	2022/11/17
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AGREEMENT ON PROMOTERSHIP

March 12, 2024

This agreement is made between:

ENGR. TEOFILO M. SAGABAEN
(Name of Adviser-Promoter/ Signature over Printed Name)

As the promoter, I agree to dispense the duties and responsibilities as indicated:

1. Aid the research team conceptualize and develop a research problem based on Research Agenda and check its progress;
2. Write initial inputs on appropriate research design and techniques and assist the team to craft or adapt appropriate tool(s);
3. Assist the research team in preparing for the defenses and tutor them on how to make good in their presentations;
4. Check the integration of suggestions made by the technical panel and guide the research teams in the enrichment of the manuscript;
5. Advise the research team for the ethical review of the proposal manuscript and direct them in the integration of comments;
6. Suggest helpful methods and/or techniques in the collection of data;
7. Conduct blended mentoring sessions with advisees from conceptualization to submission;
8. Attend to the inquiries of the research team for further development of the manuscript;
9. Monitor the performance of the research team from the write-up to the conduct of the research;
10. Aid the research teams in presenting, analyzing and interpreting data; and
11. Make initial editing and proofreading works from proposal to full paper.

and

(Students' names and signatures)

RAYNE ANGELICA O. NAVAL — RAIZEL JO PAGADA

LIEZEL MAE P. ARAOS — NOEMI SHANE R. PUYALES

Inspired by Mission,
Driven by Excellence

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SMU Main Campus, Ponce Street,
Bayombong, 3700 Nueva Vizcaya, Philippines
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09755114139 / 09654317801

As researchers, we agree to conduct the research project under the supervision of our adviser-promoter; and expected to:

a) Write the topic proposal under the supervision of our adviser-promoter;
b) Report to our adviser-promoter on a regular basis to guarantee development of the manuscript;
c) Perform research tasks assigned by our adviser-promoter;
d) Follow the technical writing aspects of the paper;
e) Present proposal paper (during Research 1) and defend the final thesis (in Research 2) through the guidance of our adviser-promoter;
f) Integrate comments and suggestions made by the technical panel of evaluators and by the UREB reviewers;
g) Do data gathering and initial coding of data in excel format through the assistance of our adviser-promoter;
h) Write the full manuscript;
i) Disseminate research results in a forum; and
j) Submit required outputs (Bound full manuscript, IMRAD publishable format & CDs).

We do hereby abide and affix our signatures with the above-mentioned duties and responsibilities for the success of this research endeavor.

OFFICIAL CO-CURRICULAR TRANSCRIPT

Name:	**RAYNE ANGELICA O. NAVAL**
Address:	Bayombong, Nueva Vizcaya
Email address:	hed-ranaval@smu.edu.ph
Contact number:	09691855774

PERSONAL INFORMATION			
Age:	20	Date of Birth:	October 4, 2003
Civil Status:	Single	Place of Birth:	Cordon, Isabela
Religion:	Roman Catholic	Father's name:	ERWIN D. NAVAL
		Mother's name:	RONALYN O. NAVAL

EDUCATIONAL BACKGROUND		
	Name of School	**Date completed**
Tertiary	Saint Mary's University	N/A
Secondary	Saint Mary's University	January 1, 2021
	Saint Mary's University	January 1, 2019
Elementary	Saint Mary's University	January 1, 2015

MARIAN CORE VALUES

EXCELLENCE (It refers to academic/ scholastic accomplishments and involvement in non-academic activities wherein the students develop knowledge, competencies, and skills)

Award	**Event / Competition**	**Date**
Bronze Merit	Saint Mary's University	2022
Bronze Merit	Saint Mary's University	2023
Bronze Merit	Saint Mary's University	2024

INNOVATION (It refers to creative output such as research papers, capstone projects, systems developed, and students' involvement in literary, arts and visual performances)

Involvement	Seminar / Convention	Date
Participant	Flutter	2023
Participant	Cyber Security	2023

COMMUNION (It refers to students' involvement in school and community activities and leadership / trainings attended / conducted)

A. SCHOOL INVOLVEMENT

Designation	Organization	Date
Member	MICRO - JPCS	PRESENT

B. LEADERSHIP TRAININGS/SEMINARS

Involvement	Seminar / Training	Date
Participant	Leadership Traning	2018

PASSION FOR CHRIST'S MISSION (It refers to students' involvement in spiritual and pastoral activities)

Involvement	Event	Date
Participant	Recollection	2018
Participant	Recollection	2017
Participant	Recollection	2016
Participant	Recollection	2015
Participant	Recollection	2024
Participant	Takbokasyon	2022
Participant	Takbokasyon	2023

Note: Delete unused rows. Removed table borders when done

TECHNICAL SKILLS / COMPETENCIES
Basic knowledge in Programming (Java Eclipse, Visual Basic, Arduino, PLC, MATLAB, HTML, C++, Python)
Video Editing
Literary Writing
Graphic Design

OFFICIAL CO-CURRICULAR TRANSCRIPT

Name:	**RAIZEL JOY LAPADA**
Address:	Villaverde, Nueva Vizcaya
Email address:	Hed-rjlapada@smu.edu.ph
Contact number:	09214981583

PERSONAL INFORMATION			
Age:	20	Date of Birth:	August 1. 2003
Civil Status:	Single	Place of Birth:	Villaverde, Nueva Vizcaya
Religion:	Roman Catholic	Father's name:	SEGUNDO B. LAPADA JR.
		Mother's name:	ROWENA E. LAPADA

EDUCATIONAL BACKGROUND		
	Name of School	**Date completed**
Tertiary	Saint Mary's University	N/A
Secondary	Our Lady of Fatima School of Villaverde	2021
	Our Lady of Fatima School of Villaverde	2019
Elementary	Nagbitin Elementary School	2015

MARIAN CORE VALUES

EXCELLENCE (It refers to academic/ scholastic accomplishments and involvement in non-academic activities wherein the students develop knowledge, competencies, and skills)

Award	**Event / Competition**	**Date**
Dean's Lister	Saint Mary's University	2022
Dean's Lister	Saint Mary's University	2023
Dean's Lister	Saint Mary's University	2023

INNOVATION (It refers to creative output such as research papers, capstone projects, systems developed, and students' involvement in literary, arts and visual performances)

Involvement	Seminar / Convention	Date
Participant	Cyber Security	2023
Participant	Flutter	2023
Participant	Basics of Filming	2023

COMMUNION (It refers to students' involvement in school and community activities and leadership / trainings attended / conducted)

C. SCHOOL INVOLVEMENT

Designation	Organization	Date
Member	MICRO - JPCS	PRESENT

D. LEADERSHIP TRAININGS/SEMINARS

Involvement	Seminar / Training	Date
N/A	N/A	N/A

PASSION FOR CHRIST'S MISSION (It refers to students' involvement in spiritual and pastoral activities)

Involvement	Event	Date
Participant	Takbokasyon	2023
Participant	Takbokasyon	2022
Participant	Recollection	2024

TECHNICAL SKILLS / COMPETENCIES
Video Editing
Programming Java, C#, Visual Basic

OFFICIAL CO-CURRICULAR TRANSCRIPT

Name:	**NOEMI SHANE R. PUYALES**
Address:	Darubba, Quezon, Nueva Vizcaya
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Contact number:	09155614823

PERSONAL INFORMATION			
Age:	21	Date of Birth:	October 25, 2002
Civil Status:	Single	Place of Birth:	Darubba, Quezon, Nueva Vizcaya
Religion:	Baptist	Father's name:	NOEL M. PUYALES
		Mother's name:	MARIA CRISTINA R. PUYALES

EDUCATIONAL BACKGROUND		
	Name of School	**Date completed**
Tertiary	Saint Mary's University	N/A
Secondary	Saint Louis School	January 1, 2021
	Saint Louis School	January 1, 2018
Elementary	Aldersgate College	January 1, 2014

MARIAN CORE VALUES

EXCELLENCE (It refers to academic/ scholastic accomplishments and involvement in non-academic activities wherein the students develop knowledge, competencies, and skills)

Award	**Event / Competition**	**Date**
Dean's Lister	Saint Mary's University	2022
Dean's Lister	Saint Mary's University	2023
Dean's Lister	Saint Mary's University	2024

INNOVATION (It refers to creative output such as research papers, capstone projects, systems developed, and students' involvement in literary, arts and visual performances)

Involvement	Seminar / Convention	Date
Participant	Cyber Security	2023
Participant	Flutter	2023
Participant	Basics of Film Making	2023

COMMUNION (It refers to students' involvement in school and community activities and leadership / trainings attended / conducted)

E. SCHOOL INVOLVEMENT

Designation	Organization	Date
Member	MICRO - JPCS	PRESENT

F. LEADERSHIP TRAININGS/SEMINARS

Involvement	Seminar / Training	Date
N/A	N/A	N/A

PASSION FOR CHRIST'S MISSION (It refers to students' involvement in spiritual and pastoral activities)

Involvement	Event	Date
Participant	Takbokasyon	2023
Participant	Takbokasyon	2022
Participant	Recollection	2024

TECHNICAL SKILLS / COMPETENCIES
Video Editing
Programming Java, C#, Visual Basic

OFFICIAL CO-CURRICULAR TRANSCRIPT

Name:	**LIEZEL MAE P. ARAOS**
Address:	Solano, Nueva Vizcaya
Email address:	Hed-lmaraos@smu.edu.ph
Contact number:	09926973266

PERSONAL INFORMATION			
Age:	20	Date of Birth:	October 29, 2003
Civil Status:	Single	Place of Birth:	Solano, Nueva Vizcaya
Religion:	Methodist	Father's name:	ANGELITO S. ARAOS
		Mother's name:	MILA P. ARAOS

EDUCATIONAL BACKGROUND		
	Name of School	**Date completed**
Tertiary	Saint Mary's University	N/A
Secondary	Saint Louis School	2021
	Saint Louis School	2019
Elementary	Solano West Elementary School	2015

MARIAN CORE VALUES

EXCELLENCE (It refers to academic/ scholastic accomplishments and involvement in non-academic activities wherein the students develop knowledge, competencies, and skills)

Award	**Event / Competition**	**Date**
Dean's Lister	Saint Mary's University	2022

INNOVATION (It refers to creative output such as research papers, capstone projects, systems developed, and students' involvement in literary, arts and visual performances)

Involvement	**Seminar / Convention**	**Date**
Participant	Flutter	2023

Participant	Cyber Security	2023

COMMUNION (It refers to students' involvement in school and community activities and leadership / trainings attended / conducted)

G. SCHOOL INVOLVEMENT

Designation	**Organization**	**Date**
Member	MICRO - JPCS	PRESENT
Sports Coordinator	MICRO - JPCS	PRESENT

H. LEADERSHIP TRAININGS/SEMINARS

Involvement	**Seminar / Training**	**Date**
N/A	N/A	N/A

PASSION FOR CHRIST'S MISSION (It refers to students' involvement in spiritual and pastoral activities)

Involvement	**Event**	**Date**
Participant	Takbokasyon	2023
Participant	Takbokasyon	2022
Participant	Recollection	2024

TECHNICAL SKILLS / COMPETENCIES
Video Editing
Programming Java, C#, Visual Basic

OFFICIAL CO-CURRICULAR TRANSCRIPT

Name:	**MC OSMUND CAESAR L. ESPEJO**
Address:	#110 National Rd. District 4 Bay, NV
Email address:	akillerjam@gmail.com
Contact number:	0999 399 1144

PERSONAL INFORMATION			
Age:	21	Date of Birth:	November 28, 2002
Civil Status:	Single	Place of Birth:	R2TMC
Religion:	Iglesia Ni Cristo	Father's name:	OSMUNDO R. ESPEJO
		Mother's name:	MARJORIE L. ESPEJO

EDUCATIONAL BACKGROUND

	Name of School	**Date completed**
Tertiary	Saint Mary's University	N/A
Secondary	Saint Mary's University Senior High School	2021
	Saint Mary's University JuniorHigh School	2019
Elementary	Bayombong Central School SPED-Center	2015

MARIAN CORE VALUES

EXCELLENCE (It refers to academic/ scholastic accomplishments and involvement in non-academic activities wherein the students develop knowledge, competencies, and skills)

Award	**Event / Competition**	**Date**
Silver Merit	Saint Mary's University	2022
Bronze Merit	Saint Mary's University	2023
Bronze Merit	Saint Mary's University	2024

INNOVATION (It refers to creative output such as research papers, capstone projects, systems developed, and students' involvement in literary, arts and visual performances)		
Involvement	**Seminar / Convention**	**Date**
Participant	ITIL	2024
COMMUNION		
I. SCHOOL INVOLVEMENT		
Designation	**Organization**	**Date**
Member	MICRO - JPCS	PRESENT
J. LEADERSHIP TRAININGS/SEMINARS		
Involvement	**Seminar / Training**	**Date**

PASSION FOR CHRIST'S MISSION (It refers to student's involvement in spiritual and pastoral activities)		
Involvement	**Event**	**Date**
Participant	Takbokasyon	2022
Participant	Recollection	2024
TECHNICAL SKILLS / COMPETENCIES		
Basic Knowledge in Java, VB.Net, MERN		