

**UNIVERSITI TEKNOLOGI MARA**

**FEASIBILITY STUDY OF A  
COMPUTERISED MAINTENANCE  
MANAGEMENT SYSTEM FOR A  
UNIFIED ROAD ELECTRICAL  
ASSET MONITORING SYSTEM**

**AMAR AMJAD  
BIN ABDUL WAHID**

**MSc**

**February 2026**

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**AMAR A MJAD  
BIN ABDUL WAHID**

Thesis submitted in fulfilment  
of the requirements for the degree of  
**Master of Science**  
**(Logistics & Transport)**

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**February 2026**

## CONFIRMATION BY PANEL OF EXAMINERS

I certify that a Panel of Examiners has met on 23 October 2025 to conduct the final examination of Amar Amjad Bin Abdul Wahid on his Masters of Science thesis entitled "Feasibility Study Of A Computerised Maintenance Management System For A Unified Road Electrical Asset Monitoring System" in accordance with Universiti Teknologi MARA Act 1976 (Akta 173). The Panel of Examiner recommends that the student be awarded the relevant degree. The Panel of Examiners was as follows:

Rafeah Legino, PhD  
Associate Professor  
Faculty of Arts & Design  
Universiti Teknologi MARA  
(Chairman)

Ahmad Afif Ahmarofi, PhD  
Senior Lecturer  
Faculty of Computer and Mathematical Science  
Universiti Teknologi MARA  
(Internal Examiner)

Zulkifli Mohd Nopiah, PhD  
Associate Professor  
Department of Engineering Education  
Universiti Kebangsaan Malaysia  
(External Examiner)

**PROFESSOR DR HJH ZURAEDA  
IBRAHIM**

Dean  
Institute of Postgraduate Studies  
Universiti Teknologi MARA  
Date: 26 February 2026

## AUTHOR'S DECLARATION

I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Teknologi MARA. It is original and is the results of my own work, unless otherwise indicated or acknowledged as referenced work. This thesis has not been submitted to any other academic institution or non-academic institution for any degree or qualification.

I, hereby, acknowledge that I have been supplied with the Academic Rules and Regulations for Postgraduate, Universiti Teknologi MARA, regulating the conduct of my study and research.

Name of Student	Amar Amjad Bin Abdul Wahid
Student ID. No.	2023656924
Programme	Master of Science in Logistics & Transport - LT780
Faculty	Malaysian Institute of Transport (MITRANS)
Thesis Title	Feasibility Study of A Computerised Maintenance Management System For A Unified Road Electrical Asset Monitoring System
Signature of Student	
Date	February 2026

## ABSTRACT

This research investigates the feasibility of integrating a Computerised Maintenance Management System (CMMS) into the Road Electrical Asset Control & Telemetry (REACT) system for managing public road electrical assets. The study focuses on the Public Works Department (PWD) Selangor's implementation of REACT, with emphasis on traffic lights and street lighting, excluding other assets such as underground cables, closed-circuit television (CCTV), and flood monitoring sensors. The research aimed to: (i) identify the key requirements for effective maintenance of road electrical assets, (ii) develop a CMMS model tailored for integration with REACT, and (iii) evaluate the operational feasibility of the proposed integration using quantitative and qualitative assessments. A mixed methods approach was adopted, consisting of three methodological components: (i) document analysis of maintenance records, system documents, and asset-related forms; (ii) Monte Carlo simulation of failure breakdown scenarios patterns and simulation iterations to estimate improvements in resolution times; and (iii) a focus group discussion (FGD) with PWD stakeholders, analysed thematically to assess operational readiness, system gaps, and user expectations. These complementary methods enabled triangulation of findings to assess the technical suitability, performance impact, and user acceptance of the CMMS REACT model. The results indicate three major findings. First, REACT already contains CMMS compatible features such as asset inventory, alert notifications, and multi brand device integration, demonstrating a foundational readiness for integration. Second, simulation outcomes showed measurable operational improvements, including an 11% reduction in fault resolution time after applying CMMS based scheduling, work order structuring, and maintenance tracking. Third, stakeholder insights highlighted enhanced preventive maintenance, fewer emergency repairs, and improved data centralisation as key benefits, while also identifying gaps such as inconsistent historical repair data and the need for user training and workflow standardisation. Overall, the proposed CMMS to REACT model offers a structured, data driven framework for transitioning from reactive to proactive maintenance management. The study contributes to the body of knowledge in infrastructure asset management by providing an empirically validated integration model and demonstrating its applicability within a Malaysian public-sector context. The findings offer a replicable approach for public agencies aiming to improve asset reliability, extend lifecycle performance, and optimise resource allocation.

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## LIST OF ABBREVIATIONS

### Abbreviations

AC	Asset Condition
ACr	Asset Criticality
Ai	Artificial Intelligence
AM	Asset Management
CMS	Condition Monitoring System
CM	Corrective Maintenance
CMMS	Computerised Maintenance Management System
CP	Cumulative Probability
CR	Complaint Registration
CCTV	Closed-Circuit Television
DCS	Distributed Control System
EB	Event Based
EMS	Energy Monitoring System
FAT	Factory Acceptance Test
FIR	Failure and Incident Report
GM	Green Maintenance
IIoT	Industrial Internet of Things
IM	Inventory Management
JKR	Jabatan Kerja Raya

KPI	Key Performance Indicator
KKR	Kementerian Kerja Raya
LM	Lean Maintenance
LLM	Lembaga Lebuhraya Malaysia
MC	Monte Carlo
MCS	Monte Carlo Simulation
MHA	Malaysian Highway Authority
MTBF	Mean Time Between Failures
MTTR	Mean Time To Repair
O&M	Operation and Maintenance
PBT	Pihak Berkuasa Tempatan
PC	Preventive Corrective Maintenance
PM	Preventive Maintenance
PRI	Preliminary Review and Inspection
PWD	Public Works Department
RCM	Reliability-Centred Maintenance
REACT	Road Electrical Asset Control & Telemetry
RNG	Random Number Generator
RM	Reporting Management
RO	Research Objective
RQ	Research Question
RT	Real-Time Based

SCADA	Supervisory Control and Data Acquisition
SL	Street Lighting
SP	Spare Parts
TL	Traffic Light
TPM	Total Productive Maintenance
VC	Corrective (Breakdown) Maintenance
VMS	Vehicle Monitoring System
WOR	Work Order Resolution Time

# CHAPTER 1

## INTRODUCTION

### 1.1 Research Background

The total length of public roads in Malaysia are over 300,000 kilometres and are managed by few government agencies either state or federal agencies. Four most recognisably known organisation to manage these public roads in Malaysia are the Jabatan Kerja Raya (JKR) or the Public Work Departments (PWD), second is the Lembaga Lebuhraya Malaysia (LLM) or the Malaysian Highway Authorities (MHA), third is the Pihak Berkuasa Tempatan (PBT), local authorities or the local municipal council and fourth is the Kementerian Pembangunan Luar Bandar (KPLB) or Ministry of Rural Development (MRD).

PWD is managing most of the public roads in Malaysia in total length of 302,868.547 kilometres recorded as of 2021 (CSFJ JKR Malaysia, 2022). for both state and federal roads. For having profound historical background since the Straits Settlements 1872 lead by Major J.F.A. McNair, PWD have gone through era of independence 1957, through the formation of Malaysia 1963 and through various economic and technological landscapes. PWD on this presence have serve to be an important agency under the Kementerian Kerja Raya (KKR) or the Ministry of Works (MOW) (JKR Malaysia, 2024). Roads under the governance of PWD are those major trunks with access towards cities and connecting cities and until today.

One of the major components in public road safety installations are traffic light and street lighting. Within Public Work Department, these assets are both responsibly managed by the Electrical Department. The numbers of total street lightings installed until today are 119,197 set on different roads while traffic lights with 1,898 unit of controller junctions scattered across the nation (CSFJ JKR Malaysia, 2022). Most complaints received by PWD for roads maintenance are mostly categorised into potholes, failure of street lightings or presence of illumination and traffic lights incompetence. Without proper maintenance, assets will have lower life span and are expected for failure.

Street lighting (SL) plays a pivotal role not just in the urban landscape, shaping the way we navigate our cities but it also enhancing safety and contributing to the overall driving performance. As a component of modern infrastructure, these lighting also illuminates our public spaces or compound area. Beyond its aesthetic and navigational significance, effective street lighting holds the potential to reduce accidents and deter criminal activity. In 2021 reports of broken street lighting had caught lives in Batu Pahat due to low night visibility and the increased numbers of cars, these issues are worrying other road users and provide danger to users (Utusan, 2021).

While Traffic lights (TL) stand as the guardians of our roads, playing a paramount role in ensuring road safety in an orderly traffic flow. These meticulously programmed timed signals, composed of red, amber, and green phases, guide the complex path of vehicles, pedestrians, and cyclists at junction intersections. Its potential is massive on our roadways minimizing the risk of collisions, reduce congestion, and mitigating life-threatening accidents. Their mechanisms symbolize the delicate balance between efficiency and safety landscapes. In 2022, the Deputy Minister of the Ministry of Federal Territories explained that one of the factors causing extraordinary traffic congestion in the capital city was the failure of traffic signal system. He mentioned that this was due to the management of traffic signal systems within and around urban areas that lack uniformity (Malaysia Gazette, 2022). Hence, a proper management system for managing road assets especially traffic signal lights is a necessity for ensuring a smooth and sustainable traffic.

As these emerging technologies and connected systems promising to further enhance their capacity to improve roads safety infrastructure not just to protect lives but also gave a spillover effect towards a smooth streamline of transportation networks. Throughout the world many asset monitoring systems specific for electrical equipment's including Supervisory Control and Data Acquisition (SCADA), Light Detection Ranging (LiDAR), Distributed Control System (DCS), Condition Monitoring System (CMS), Vehicle Monitoring System (VMS), Energy Monitoring System (EMS) and Industrial Internet of Things (IIoT) for traffic management systems have been introduced and applied by many agencies and various organisations. Despite the advancement of features and characteristics of the system, they all serve to monitor the health of the assets and hoping to increase its life expectancy. Two approaches of

detecting asset problem come from the organization or from road users and ways of reporting traffic light failures or street lighting was described in a news article was through emails of local authorities or their official social media accounts (Roda Panas, 2023).

The Electrical Engineering Unit, Public Work Department of Selangor have made the efforts to develop a monitoring system to manage and monitor electrical assets to improve organizational productivity and forecasting asset ability and downtime. The unique value proposition of this system is an all-in-one unified platform for monitoring electrical assets which includes Traffic Lights (TL), Street Lighting (SL), Artificial Intelligence (Ai) Camera and other electrical assets from multiple brand suppliers. A unified electrical asset monitoring system represents a key leap in the management and maintenance of electrical infrastructure. By seamlessly integrating various monitoring technologies and data sources, it provides a holistic view of an organization's electrical assets. This innovative approach can harness real-time data and analytics to optimize asset performance, predict potential failures, and enhance operational efficiency through a centralized platform. A unified systems empowers decision-makers enabling them to proactively address issues on minimize downtime and maximize the lifespan of critical electrical assets.

The unified system by PWD Selangor is called Road Electrical Asset Control & Telemetry (REACT) developed by CKE JKR Selangor venture with the system integrator Lorant Technologies PLT. The system was established in 2020 in its efforts to monitor multiple traffic light brand in one unified system. The system successfully recognised by many brand suppliers, in 2021 the system expands its technology usage to multiple brands of street lighting technology. Its aim is to monitor electrical assets majorly for real time viewing and real time breakdowns and easily access through its web-based system and simple receiving notifications. In an era where reliability and sustainability are paramount, a unified electrical asset monitoring system like this must emerge as a strategic imperative for utilities and industries alike to promotes reliability, resilience, and resource efficiency.

## **Computerised Maintenance Management System (CMMS) For Electrical Maintenance**

In the context of asset management and maintenance systems, the selection of practices in maintenance and its effective implementation is crucial to ensure the sustaining longevity, reliability, and cost-effectiveness to maintain the assets. A guiding principles or philosophies in maintaining and managing the assets should encompasses a set of methodologies that organization should oblige to optimize their maintenance processes.

Additionally, a Computerised Maintenance Management System (CMMS) a software or tool in the period of electrical asset management and maintenance system can be facilitated to help monitor these assets. CMSS can be structured into few major items such as asset database, maintenance scheduling, work order management, inventory management, asset tracking and monitoring, compliance, and documentation, reporting or analytics, mobile accessibility and open for integration.

Computerise Maintenance Management System (CMMS) have been available since 1960s to monitor assets and have been shifting to Web based or Cloud Based and becoming more complex with the advancements of analytics and IoT integration. These dynamic process or practice can benefits asset managers to incorporate with artificial intelligence, machine learning and big data that can further enhance the maintenance management capabilities. With its depth of impact, a CMMS practices for maintaining road electrical asset should be foster and enhance to implement in organizations.

## 1.2 Problem Statement

At both state and federal levels, Public Works Department (PWD) plays a prominent role compared to other agencies to oversee the extensive public road network. The performance of road electrical assets especially traffic lights and street lighting is essential for public safety, mobility, and the overall functioning of Malaysia's road network. In Selangor, the Public Works Department (PWD) manages a large and diverse inventory of these assets across both urban and rural areas. However, the maintenance of these assets continues to face significant challenges. Faults are frequently reported, many take longer than expected to be resolved, and maintenance activities are often carried out without complete repair records or standardised procedures. These issues contribute to traffic delays, reduced night-time visibility, safety hazards for road users, and higher operational costs. The persistence of such problems indicates that the current maintenance approach is not meeting the needs of a modern and rapidly evolving road infrastructure system.

To improve monitoring, PWD Selangor introduced the Road Electrical Asset Control & Telemetry (REACT) system. While REACT is effective in providing real-time alerts and visibility of device status, it remains primarily a monitoring platform. It does not include key Computerised Maintenance Management System (CMMS) functions such as preventive maintenance planning, automated work orders, asset lifecycle tracking, contractor performance reporting, or analytical tools such as Mean Time to Repair (MTTR) and downtime analysis. As a result, maintenance practices still depend heavily on manual coordination and reactive responses, and lack the structured processes needed to ensure consistent and efficient asset management.

This mismatch between what REACT provides real-time monitoring and what PWD requires a structured, data driven maintenance system forms a clear operational gap. Without an integrated CMMS, PWD cannot fully track asset history, analyse long term trends, plan preventive interventions, or justify resource allocation based on evidence. Observed issues such as repeated failures on the same assets, inconsistent documentation across districts, and delays in contractor response all point to the same underlying problem which is the absence of a CMMS unified maintenance management framework.

Given these challenges, it is necessary to examine whether integrating CMMS capabilities into REACT system would improve maintenance effectiveness, reduce operational delays, and support more proactive management of road electrical assets. This research is therefore motivated by the need to address the limitations of the current system, provide evidence on the potential benefits of a CMMS to REACT integration, and determine whether such integration is technically and operationally feasible for PWD Selangor.

### **1.3 Research Questions**

Based on the background of study and the problem statement given, there are few research questions

- a) What are the key maintenance requirements and system feature necessary to support effective management of road electrical assets?
- b) How can a CMMS be systematically integrated into the existing REACT platform to support preventive and corrective maintenance?
- c) How can a CMMS be systematically integrated into the existing REACT platform to support preventive and corrective maintenance?

### **1.4 Research Objectives**

- i) To identify and analyse the key maintenance requirements for road electrical asset
- ii) To design and propose an integration framework for CMMS within the existing REACT system.
- iii) To evaluate the operational feasibility of the proposed CMMS REACT integration using simulation and stakeholder assessment

### **1.5 Significance of Study**

This study will give a paramount impact on road maintenance organizations such as Local Authorities, Public Work Department (PWD), Local Municipalities, City Planner or Highway Authorities on managing an extensive public road network and critical electrical assets. Despite existing efforts of modern monitoring system like REACT system, the study highlights the compelling need for a Computerized Maintenance Management System (CMMS) tailored with modern asset management practices to manage road electrical assets.

## **1.6 Scope & Limitation**

The scope is focussing on major electrical assets on roads such as Traffic Lights and Street Lightings while excluding underground cables and other related assets such as CCTV. The assets monitored to be used in case study is within the public roads or highways managed by Public Work Departments (PWD) and the system is based on Road Electrical Asset Control & Telemetry (REACT). The field of CMMS is magnitude into two major maintenance practices which are Preventive Maintenance and Corrective Maintenance.

The study examines the feasibility of integrating a Computerised Maintenance Management System (CMMS) into REACT by analysing current maintenance practices, which encompass both preventive maintenance and corrective maintenance. The scope also includes the use of historical fault records, complaint data, and workflow analysis to support simulation-based evaluation using the Monte Carlo method and validation through stakeholder feedback.

This study does not calculate the full cost of CMMS implementation, as cost elements could not be determined, therefore the feasibility analysis relies more on the alternative performance metrics such as complaint resolution time. The research is geographically limited to PWD State of Selangor, and the findings may not fully represent operational conditions in other states.

Only two asset categories traffic lights and street lighting were included in the analysis, while other road electrical assets remain outside the study's scope. The simulation relies on historical complaint data, which may contain incomplete or inconsistent entries, and applies assumptions such as distribution-based fault occurrences and fixed CMMS improvement percentages, which may not fully represent real case behaviour.

Furthermore, the study does not involve a live CMMS pilot implementation, and therefore relies on workflow analysis, and stakeholder input, which may introduce subjective limitations.

## **CHAPTER 2**

### **LITERATURE REVIEW**

#### **2.1 Introduction**

The literature review in this study provides an exploration of the existing system in the field of road asset management and monitoring systems. It delves into the definition of unified systems, their characteristics, and their application in the management of road assets. By examining key scholarly works, this literature review aims to establish a solid foundation for the subsequent research to offer insights into the current state of maintenance practices for electrical road asset management practices and identifying areas where improvements can be proposed.

#### **2.2 Unified Road Asset Monitoring System.**

The definition of a unified system is discussed, and few characteristics were highlighted. Then, examining the overview of Road Electrical Asset Control & Telemetry (REACT) system can determine the need of implementing CMMS. The difference between asset monitoring system and asset management system is also explained to differentiate and achieve balance between immediate operational needs and strategic decision-making for asset management.

##### **2.2.1 Definitions of a Unified Systems**

In the realm of asset monitoring and management, the concept of unified systems has gained prominence as organizations seek solutions to streamline their operations and increase efficiency.

Unified systems, in this context, refer to integrated platforms or approaches that consolidate diverse functions and data sources into a cohesive framework. Their application in asset monitoring and management is the key characteristics that make them effective tools for modern organizations. The development of science and

information technology has brought about rapid changes in various industries, including asset management (Athoillah & Pratiwi, 2018).

Unified systems, also known as integrated systems, is a comprehensive platform that bring together various elements or components into a single, harmonized framework. These systems are designed to overcome the challenges of siloed data, disjointed processes, and fragmented functionalities. By unifying disparate elements, organizations can achieve a holistic view of their operations, which is crucial for informed decision-making. Unified systems often incorporate technologies such as data integration, automation, and centralized control to achieve their objectives. The implementation of technology, such as web-based asset management information systems, has greatly improved asset tracking and management processes. These systems have the capability to provide quality data and can be accessed efficiently and effectively by all users within an organization (Sinulingga et al., 2022).

In the context of asset monitoring and management, unified systems play a pivotal role in optimizing the utilization and performance of critical assets, such as road electrical assets. Unified systems in asset monitoring and management have become increasingly important in modern organizations. This is due to several reasons. Firstly, operational activities in an organization often trigger assets to enter and exit, without an integrated system in place, asset management can become overwhelming and inefficient (Kusuma & Muttaqin, 2022).

These systems offer a centralized platform for monitoring, maintenance, and decision support. For example, the integration of various electrical asset monitoring components, such as traffic lights, street lighting, and environmental sensors, into a unified system enables real-time data collection, predictive maintenance, and efficient resource allocation. This integration streamlines workflows, can reduces downtime, and enhances the overall effectiveness of asset management.

Several key characteristics, define unified systems in the context of asset monitoring and management:

*Integration & Centralization:* One of the key characteristics that make unified systems effective tools for modern organizations is their ability to integrate diverse functions and data sources. By integrating different functions and data sources into a central system, unified systems provide a cohesive framework for asset monitoring and

management. This integration allows organizations to streamline their processes, improve data accuracy, and enhance decision-making capabilities. Garramone et al. (2020) stated that a management system has the potential to improve information management operations and provide advantages in process control and delivery of quality. Unified systems seamlessly integrate diverse data sources, devices, and processes, allowing for a holistic view of asset performance and health.

*Real-time Monitoring:* Another important characteristic of unified systems in asset monitoring and management is real-time monitoring capabilities. Real-time monitoring allows organizations to track the status and condition of assets in real-time, enabling proactive maintenance and minimizing downtime. This capability is crucial in industries where asset reliability and efficiency are paramount, such as manufacturing or transportation logistics (Dubolazov et al., 2019). Unified systems often offer real-time monitoring capabilities, enabling immediate responses to asset issues and reducing the risk of failures.

*Predictive Analytics:* Predictive analysis is another key characteristic of unified systems in asset monitoring and management. By analysing historical data and using advanced algorithms, unified systems can predict potential asset failures or maintenance needs. This enables organizations to plan and allocate resources more effectively, minimize unplanned downtime, and optimize asset performance (Márquez et al., 2020). They incorporate predictive analytics to forecast maintenance needs, helping organizations proactively address potential problems.

*Interoperability:* Unified systems in asset monitoring and management also possess interoperability. Interoperability allows different systems and devices to seamlessly communicate and exchange data, ensuring that information flows smoothly across the organization. This interoperability enables better coordination and collaboration between different departments or teams involved in asset monitoring and management, leading to more efficient operations and improved decision-making (Anumbe et al., 2022). Unified systems are compatible with various devices and technologies, facilitating seamless communication between components.

Unified systems represent a significant advancement in asset monitoring and management, offering organizations the ability to consolidate their operations, improve efficiency, and enhance decision-making. As the complexity of asset management

continues to grow, the adoption of unified systems becomes imperative for organizations seeking to optimize their resources and maintain critical infrastructure effectively.

### 2.2.2 Road Electrical Asset Control & Telemetry (REACT)

The system built by Public Work Department of Selangor are beneficial to the road management organization in terms of monitoring assets and maintenance. REACT provides a real-time data monitoring & data collection system as well as centralizing data acquisition as shown in Figure 2.1.

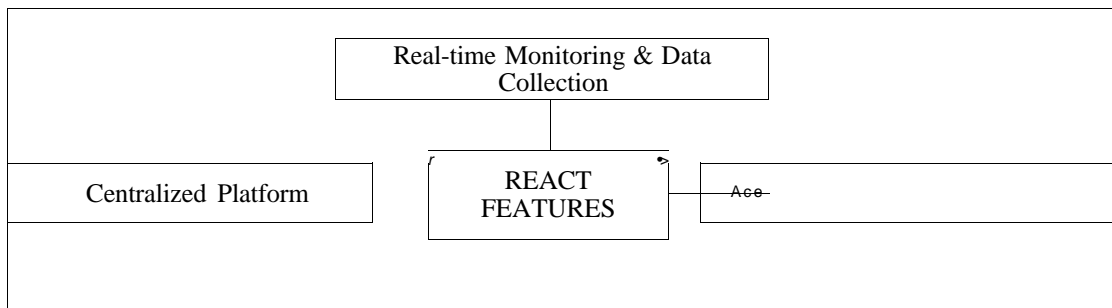


Figure 2.1 The Features of REACT Platform

In traffic lights monitoring category, it handles various types of controllers, each sourced from different supplier brands. Similarly, for street lighting, it oversees different technologies and supplier brands. REACT system also has the capability to manage CCTV systems, these features collectively provide an all-encompassing view of the electrical assets in real-time monitoring vital for ensuring road safety and overall infrastructure performance. Figure 2.2 explains the unified integrated system which is available for multiple types of brand suppliers and brand technology.

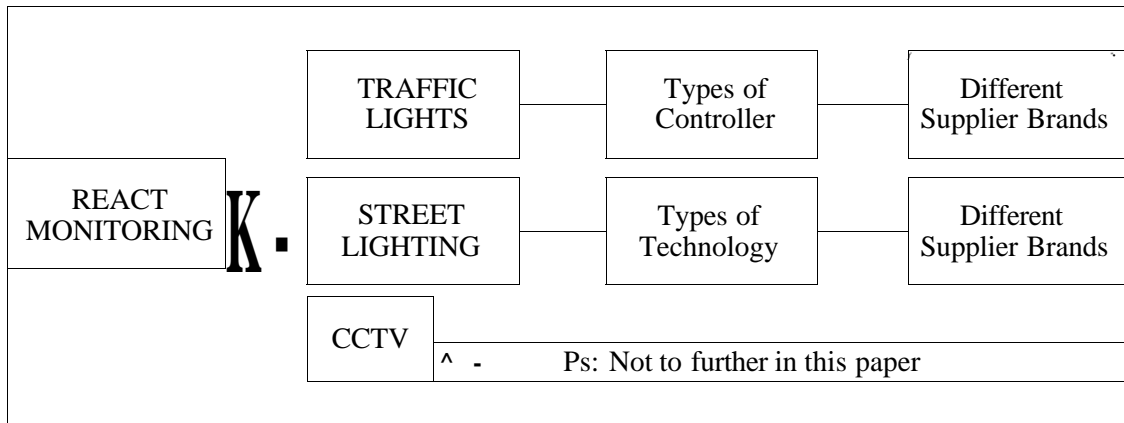


Figure 2.2 The Variation of Technology and Brands

Under the asset maintenance and management features, the asset registration process is a fundamental step in enhancing the control of electrical assets within the Road Electrical Asset Control & Telemetry (REACT) system. By registering assets, the system may ensure the availability of accurate and up-to-date information, enabling efficient monitoring practices (CKE JKR Selangor, 2023).

However, with the lack of information on maintenance needs and schedule, the evaluation of asset performance will be hard to predict and only happen due to failures or corrective maintenance. As what explained above in current monitoring system is only for event occurrences and real time-based data. With the lack of information on maintenance needs and schedule on the assets monitoring system, the evaluation of asset performance will be hard to predict and only happen due to failures or corrective maintenance.

### 2.2.3 Asset Management System versus Asset Monitoring System

Asset Monitoring Systems are geared towards real-time asset performance optimization, while Asset Management Systems takes a more holistic approach, ensuring long-term asset efficiency and sustainability. The key lies in integrating both systems to achieve a balance between immediate operational needs and strategic decision-making for asset management.

Both Asset Management Systems (AManS) and Asset Monitoring Systems (AMonS) are distinct but complementary tools in the field of asset management. Several studies have explored the differences and benefits of these systems.

Volkova & Kornienko (2014) discussed the approach in choosing an optimal asset management strategy for subsidiaries. They emphasized the need to synchronize strategies at different business levels and decompose relationships through key performance indicators. On the other hand, Alabdulkarim et al. (2015) focused on assessing asset monitoring levels for maintenance operations. They highlighted the importance of monitoring technology in improving asset availability and suggest that higher monitoring levels lead to better asset performance.

Tao et al. (2000) proposed an asset management model and systems integration approach. They introduced an operational scenario tool as an implementation strategy for asset management, emphasizing the integration objectives and unique products developed in each phase.

Similarly, Rozman et al. (2022) conducted a systematic review of studies examining the relationship between resilience and physical asset management for water systems. Dehghani et al. (2012) also presented a framework for aggregating highway asset performance measures. Their results demonstrated how decision-makers can use the framework to allocate resources effectively across different highway assets.

On much more advance note, Zuo & Qi (2022) explored a blockchain-based IoT framework for oil field remote monitoring and control. They demonstrated the system's capability to generate immutable and trust-less "digital twins" for industrial IoT applications.

These studies highlighted the diverse applications and benefits of Asset Management Systems and Asset Monitoring Systems in various industries, including finance, transportation, and infrastructure. The integration of these systems can lead to improve asset performance, resource allocation, and decision-making. However, further research is needed to explore the specific challenges and opportunities associated with the integration of these systems in different contexts.

## **2.3 Maintenance Principles and Practices**

For maintenance principle and practices, there is a need to understand the general principles and practices which is commonly used in managing road assets. The types of maintenance applied determines the reliability of assets and safety of road users.

### **2.3.1 Maintenance Definitions**

Maintenance can be defined as the set of activities and processes undertaken to ensure the continued functionality, reliability, and performance of systems, structures, or assets. It involves a systematic inspection, repair, replacement, and optimization of components, as well as the implementation of preventive and predictive measures to prevent or mitigate failures and breakdowns.

This explains the relativity of any asset with a maintenance practice which are needed to ensure its reliability, in other definition reliability of assets performance are crucial to any maintenance practices or principles (Tee & Ekpiwhre, 2019). One classical point of view towards the definition of maintenance are defined as an action taken to ensure that a system or components provide their intended functions when required with a key objective for restoring or preserving reliability at minimum cost (Tee & Ekpiwhre, 2019). Putting the objective to restore or preserve an asset is a foundation understanding to any maintenance work.

Maintenance in its wide and deep understanding conforms to a variety of principles and practices that have shaped many organizations, technologies, and industries. For example, maintenance is widely used to service all sorts of medical electronic devices from complex machines to simple handheld equipment, maintenance practices allow a safe use for medical officers and saving people lives (Arab-Zozani et al., 2021) . Maintenance is a crucial part of any industry to sustain its performance in terms of time, cost, environmental and productivity.

Maintenance practices and principles are essential for ensuring the adaptiveness reliability and sustainability of different systems and structures. Several major books and articles provide in-depth explanations of these practices and principles explains multiple perspectives of maintenance understanding which offers a similar aim which

are to ensure the reliability and performance of an asset at a good condition. The brief explanation of maintenance in books are explained in Table 2.2.

Table 2.1  
Different explanations of maintenance by Books

<b>Num</b>	<b>Title</b>	<b>Authors &amp; Publishers</b>	<b>Highlights</b>
1	Highway Engineering (Rogers & Enright, 2016)	Martin Rogers, Bernard Enright, Blackwell Publishing, 2016	This book explains the important of maintenance in roads stating major and minor maintenance with selection of the most effective form together with the consideration of optimum time at which this work should be undertaken
2	Handbook of Road Technology (Lay, 2009)	M. G. Lay, Spon Press, 2009	Maintenance is a process which stops or retards rather than reverses, deterioration. The book also explains the approach of maintenance and its management.
3	Highway Engineering: Planning, Design & Operations (Yang G. 2022)	Daniel J. Findley and Associates, Elsevier, Butterworth-Heinemann	Highlights the maintenance activities under the fiscal constraints, the maintenance is needed for every component of roads
4	The Handbook of Highway Engineering (Fwa, 2006)	T. F. Fwa, Taylor & Francis	Maintenance is a suitable routine, periodic and urgent activities to keep pavement, shoulders, slopes, drainage facilities and all other structures and property within the road margins as near as possible to their as constructed or renewed condition

These books and articles offer a wealth of knowledge on maintenance practices and principles, covering various industries and contexts. They provide a solid foundation for understanding and implementing effective maintenance strategies.

### 2.3.2 Two Major Types of Maintenance - Preventive & Corrective Maintenance

Preventive Based Maintenance (PBM) and Corrective Based Maintenance (CBM) are two major categories of maintenance practices commonly employed in various industries and sectors. Preventive maintenance refers to planned maintenance activities that are performed on equipment or systems to prevent failures or breakdowns. On the other hand, corrective maintenance involves repairing or fixing equipment or systems after a failure or breakdown has occurred.

In the aviation industry, Afshari et al. (2022) discussed the use of preventive maintenance as a frequent maintenance method for jet engines, considering safety demands. In the context of offshore wind turbines, Nachimuthu et al. (2019) proposed a decision-making model for corrective maintenance that also considers the opportunity to perform preventive maintenance during corrective maintenance trips.

Beneath these two strategies, lies other category of management of maintenance which include predetermined, condition-based, predictive, reactive maintenance and others as explained by Pamukovic et al., (2020) in Table 2.2.

Table 2.2  
Other Maintenance Types and Strategies

S. Num	Maintenance Types	Strategies
1	Condition-based maintenance	PM: maintenance based on performance and parameter monitoring and the subsequent actions
2	Corrective maintenance	CM: maintenance carried out after fault recognition and intended to put an item into a state in which it can perform a required function
3	Deferred maintenance	CM: maintenance which is not immediately carried out after fault detection but is delayed by given maintenance rules
4	Immediate maintenance	CM: maintenance which is carried out without delay after a fault has been detected to avoid unacceptable consequences
5	Operator maintenance	PM/CM: maintenance carried out during the time that the item is in use
6	Remote maintenance	PM/CM: maintenance carried out at the location where the item is used
7	Online maintenance	PM/CM: maintenance carried out by a user or operator
8	On-site maintenance	PM/CM: maintenance of an item carried out without physical access of the personnel to the item
9	Predetermined	PM: maintenance carried out by established intervals of time or number

	maintenance	of units of use but without previous condition investigation
10	Predictive maintenance	PM: maintenance carried out following a forecast derived from the analysis and evaluation of the significant parameters of the degradation of the item
11	Preventive maintenance	PM: maintenance carried out at predetermined intervals or according to prescribed criteria and intended to reduce the probability of failure or the degradation of the functioning of an item
12	Scheduled maintenance	PM: maintenance carried out by an established schedule or established
13	Cyclic maintenance	PM: maintenance carried out at regular intervals
14	Routine maintenance	PM/CM: maintenance activity carried out in a cyclic maintenance
15	Reactive maintenance	CM: maintenance refers to works that are carried out as a matter of urgency, usually for reasons of safety

### 2.3.3 Importance of Maintenance on Road Infrastructure towards Safety & Reliability

Road maintenance is crucial for sustainability as it involves strategies to preserve road assets, minimize environmental impacts, and enhance community well-being. Effective road maintenance practices can lead to cost savings in the long run. By addressing maintenance needs promptly and proactively, the costs associated with major repairs and reconstruction can be minimized (Pamukovic et al., 2020). This efficient use of resources contributes to the economic sustainability of road networks. Well-maintained roads also promote economic growth, access to services, and social equity in communities, contributing to a sustainable future with resilient transportation systems.

Road maintenance is critical for ensuring the reliability of transportation infrastructure. Routine upkeep, inspections, and repairs to prevent wear and tear, reducing unexpected outcomes and accidents. This reliability supports economic activities, emergency services, and providing an efficient transportation network. Well-maintained roads instil a solid confidence in users and promote smooth daily commutes, enhancing overall road system efficiency and economic productivity.

Using data-driven approaches and integration of technology can further enhance the sustainability of road maintenance. Oreto et al. (2023) discussed the use of

Infrastructure Building Information Modeling (IBIM) for life-cycle-based sustainable road pavement management. By leveraging data management and analysis capabilities, tools like IBIM can support decision-making processes that prioritize sustainable road pavement design and maintenance solutions.

By optimizing maintenance strategies, effective maintenance planning and strategies, such as reliability-centered maintenance (RCM) and condition-based maintenance can help to optimize maintenance efforts and resources. Focusing maintenance activities on critical areas and using data-driven approaches, the reliability of road infrastructure can be maximized (Tee & Ekpiwhre, 2019). With the right maintenance practices, sustainable and more reliable roads can be provided to users enabling safer roads better transportation system.

## **2.4 Road Electrical Assets**

In road electrical assets, the categorization of assets is explained. Basic function of road electrical assets especially traffic lights and street lighting and its importance are explained.

### **2.4.1 Categorization and Classification of Road Assets**

It is important to understand the classification of road assets to effectively monitor and manage them. Road assets can be broadly categorized into four main types which are road structure, functional assets, physical assets and non-related assets.

Gkovedarou, M. (2019) explained in detail the categorization and classification of road assets for highway management. The paper categorized asset into three level which consists of asset type, asset group and asset components. Table 2.3 shows the classification of assets prepared by Gkovedarou, M. (2019).

Table 2.3  
Classification Level of Road Assets

Level 1 Asset Type	Level 2: Asset Group	Level 3: Components
Road	Flexible pavements	Pavement layers (formation, road base, binder course, surface course) Other surface types e.g., paved. Hard strip/shoulder, Footway/ cycleway attached to road. Central reservation, roundabout, lay-by etc. Markings, Kerbs, Earthworks (embankments & cuttings)
	Flexible composite pavements	
	Rigid concrete pavements	
	Rigid composite pavements	
Segregated Footpath & Cycle Routes	Footpath (including PROW)	Binder course and surface course
	Bridleways (including PROW)	Formation
	Off road cycle routes	
	Pedestrian areas	
Structures	Bridges (includes subways)	Should include all components considered in the maintenance and management of these assets.
	Culverts (span < 1.5m)	
	Retaining walls	Smaller water carrying structures are considered as road drainage
	Sign/signal gantries and cantilever road signs.	
	Other assets included in this group:	
	Tunnels	
	Structural earthworks, e.g. strengthened/reinforced soils.	
	Fords and causeways	
	Cattle grids	

Highway Lighting and High Mast Lighting	Lighting columns Lighting unit attached to wall. High mast lighting	Column and foundations, Bracket, Luminaire (or other fixtures, e.g., CCTV), Control gear, switching and internal wiring cabling
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Figure 2.3 highlights that all lighting, traffic signals and electronic signals falls under the Electronic Furniture Asset Type (Gkovedarou et al., 2019). Each group has its plausible defects and corresponding maintenance techniques that need to be analysed and then undergo defects and repair techniques.

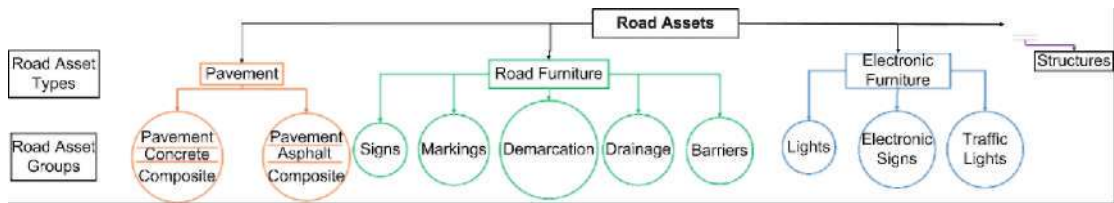


Figure 2.3 Road Asset Classification Structure

The paper explained that when an asset not working properly under the electronic asset classification, a proper technician should attend to fix the problem. This shows the importance of having the right technician to solve the problem. The Figure 2.3 shows in short, the solution to the group suggested by Gkovedarou, M. (2019).

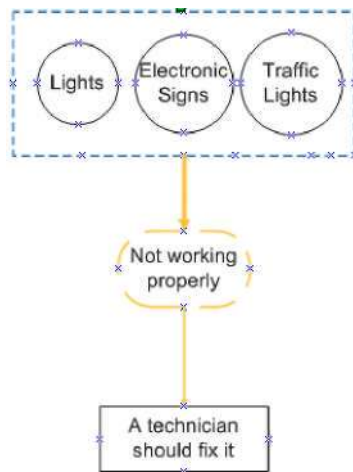


Figure 2.4 Electronic Furniture Asset Corrective Maintenance

## **2.4.2 Importance of Street Lighting Maintenance**

One important type of functional electronic asset in road infrastructure is street lighting. Street lighting plays a crucial role in ensuring the safety and visibility of roads, especially during nighttime (Czyzewski & Fryc, 2020). The effective monitoring and management of street lighting assets is essential for maintaining the functionality and safety of road networks (Beccali et al., 2017). Unified systems can be highly effective in the management of street lighting assets and the need of maintenance for this street lighting. It provides a key challenge in asset management and maintenance for street lighting assets includes tasks such as regular inspections, bulb replacements, and repairs to faulty fixtures.

Well-maintained street lighting is essential for public safety and security. Research has shown that improving street lighting can effectively combat crime (Haans & Kort, 2012). Adequate lighting in public spaces enhances visibility, making it easier for pedestrians and drivers to navigate and reducing the risk of accidents (Yusoff et al., 2020). Moreover, well-lit streets create a sense of security and deter potential criminals, contributing to a safer urban environment (Haans & Kort, 2012).

In addition to safety, street lighting maintenance also has significant implications for energy conservation and sustainability. Traditional street lighting systems often result in unnecessary wastage of electricity due to manual switching of lights when they are not required (Bhaisare, 2022). However, with proper maintenance and the implementation of smart lighting systems, energy costs can be reduced through better control of light usage (Ngo et al., 2020). Smart street lighting systems utilize sensors and advanced technologies to adjust lighting levels based on real-time conditions, ensuring that lights are only on when needed (Ngo et al., 2020). This not only saves energy but also reduces maintenance and asset management costs (Ngo et al., 2020).

Furthermore, street lighting maintenance contributes to the overall aesthetics and appearance of a city. Well-lit streets enhance the visual appeal of urban areas, creating a welcoming and vibrant atmosphere (Yusoff et al., 2020). Properly maintained lighting fixtures and infrastructure also help to establish the unique style and features of a city (Yusoff et al., 2020). This is particularly important for tourist destinations and

areas with high foot traffic, as attractive lighting can enhance the overall experience for visitors and residents alike.

In conclusion, street lighting maintenance is of paramount importance for various reasons. It enhances public safety and security, contributes to energy conservation and sustainability, improves the aesthetics of urban areas, and ensures the efficient functioning of traffic systems. By investing in regular maintenance and implementing smart lighting technologies, cities can create safer, more sustainable, and visually appealing environments for their residents and visitors.

### **2.4.3 Importance of Traffic Lights Maintenance**

Traffic signal lights maintenance is of utmost importance for several reasons. Firstly, traffic signals play a critical role in smart cities for mitigating traffic congestion and reducing emissions in metropolitan areas (Li et al., 2017). Efficient traffic signal settings can help optimize traffic flow and minimize travel time for vehicles by coordinating their movements at road intersections (Wei, 2019). Therefore, regular maintenance of traffic signal lights ensures that they are functioning properly and are synchronized to facilitate smooth traffic flow.

In heavy traffic conditions, where green times become scarce and longer queues are formed, the setting of traffic light signals becomes even more crucial (Boon et al., 2021). Proper maintenance of traffic signal lights ensures that they are adjusted to allocate optimal capacity for heavy traffic conditions, minimizing congestion and reducing delays at intersections.

Furthermore, traffic signal lights are essential signalling devices located at intersections or pedestrian crossings to control the movement of traffic (Malim et al., 2019). Regular maintenance ensures that these devices are in good working condition, allowing them to effectively communicate with drivers and pedestrians, ensuring their safety and facilitating efficient traffic management.

In recent years, the emergence of the Internet of Vehicles (IoV) introduced new possibilities for traffic signal control. Vehicular communications can be utilized to enhance traffic signal control systems, offering advantages such as no additional operational costs, lightweight computing, resilience to lighting conditions, and

resilience to harsh road conditions (Ahn & Choi, 2019). However, to fully leverage the benefits of IoV-based traffic signal control, regular maintenance of the communication infrastructure and signal lights is essential.

In conclusion, the importance of traffic signal lights maintenance cannot be overstated. It is crucial for optimizing traffic flow, reducing congestion, minimizing travel time, ensuring safety, and leveraging advancements in technology for efficient traffic signal control. Regular maintenance of traffic signal lights is necessary to ensure their proper functioning, synchronization, and adaptation to varying traffic conditions. By prioritizing maintenance efforts, cities can enhance their traffic management systems and improve the overall efficiency and safety of their transportation networks.

#### **2.4.4 Other Related Road Electrical Assets**

Street lighting and traffic lights are major electrical assets on roads and there is other which uses electricity to function and contribute to the overall functionality and safety of the road network. These may include electronic toll collection systems, variable message signs, traffic signal controllers, and surveillance cameras. Apart from those system, all input-based sensors related to road or geographical data can also be considered as road electrical assets.

Some other electrical or electronic assets are CCTV, Slope Sensor, Flood Sensor, Tunnel CO2 Sensor, Tunnel Fan System, Air Quality Management, Weather Forecasting Sensor and emergency call booth which are road assets that have its unique contribution to the road infrastructure.

In summary, a wide array of electrical assets beyond street lighting and traffic lights is also vital for the safety and efficiency of road networks. These assets serve crucial roles in monitoring conditions, enhancing security, and responding to emergencies. Recognizing and effectively managing these assets is essential for maintaining safe and reliable road infrastructure, benefiting both road users and communities.

#### **2.4.5 The Importance of Maintenance Management System**

Maintenance management software plays a crucial role in the effective management of roads and highways. These software systems are specifically designed to handle the complexities and challenges associated with maintaining large road networks (Loprencipe et al., 2017). The use of maintenance management software is becoming increasingly prevalent in the management of road infrastructures, with a growing emphasis on performance-based contracts (PBCs) for maintenance delivery (Schoenmaker & Bruijn, 2016).

One of the key benefits of maintenance management software is its ability to optimize asset management decisions. These software systems enable the implementation of key decisions related to the design, operation, maintenance, inspection, renewal, enhancement, and disposal of physical assets in the highway infrastructure (Tee & Ekpiwhre, 2019). By integrating various data sources and utilizing advanced technologies such as GIS (Geographic Information System) and BIM (Building Information Modeling), maintenance management software facilitates the dynamic sharing of information and improves the efficiency of highway management (Hao et al., 2021). This integration of information leads to better decision-making and ultimately enhances the quality of maintenance in transportation infrastructure (Hao et al., 2021).

Furthermore, maintenance management software enables the implementation of preventive maintenance strategies. By utilizing reliability-based approaches, these software systems can optimize maintenance schedules and prioritize maintenance activities based on the criticality and condition of assets (Tee & Ekpiwhre, 2019). This proactive approach to maintenance helps to prevent costly breakdowns and ensures the longevity of road infrastructure.

Another important aspect of maintenance management software is its ability to facilitate cost estimation and budget planning. By utilizing machine learning algorithms and data analytics, these software systems can estimate maintenance costs and assist in the planning and allocation of resources (Gaussmann et al., 2020). This enables road authorities to make informed decisions regarding budget allocation and optimize the utilization of available resources.

In summary, this type of maintenance management system plays a vital role in the effective management of roads and highways. These systems enable the optimization of asset management decisions, facilitate preventive maintenance strategies, improve the efficiency of highway management through information integration, and assist in cost estimation and budget planning. By leveraging advanced technologies and data-driven approaches, maintenance management software enhances the quality and sustainability of road infrastructure maintenance.

## 2.4.6 Road Asset Management Systems (RAMS)

Road Asset Management Systems (RAMS) primarily focus on monitoring and managing road infrastructure and related assets on roads. While they are primarily designed for roads and transportation systems, they can also be used for monitoring and managing various types of associated assets and furniture. Here are some common types of assets and infrastructure that can be monitored by RAMs listed in Table 2.4.

Table 2.4  
List of asset can be monitored in RAMS

<b>Asset</b>	<b>Description</b>
Road Pavement	Monitor condition of road pavements, including wear, cracks, potholes, and surface quality. The analysis of pavement condition survey data is crucial for effective implementation of a network level pavement management program (Pantuso et al., 2019).
Road junction systems	Traffic Lights or connecting systems on junctions. Road junction systems are important assets that require reliability-based preventive maintenance strategies to ensure continuous availability (Tee & Ekpiwhre, 2019)
Road network	Inventory list of road numberings and connectivity. The road network itself is a crucial asset that requires comprehensive multi-infrastructure optimization in transportation asset management (Chen et al., 2019)
Road Signs	Inventory of road signs using technology automatically scan into a system. Hu (2012) utilizes image recognition and attribute computation from video logs to improve road signs inventory log.

It is important to note that the specific assets and infrastructure monitored by RAMS may vary depending on the needs and priorities of the road management authority or organization implementing the system. The goal is to optimize the condition and performance of these assets to ensure road safety, efficiency, and sustainability.

Road asset management is a critical aspect of transportation infrastructure planning and maintenance. It involves the systematic and strategic management of road assets throughout their life cycle to ensure their optimal performance and longevity Pantuso et al. (2019). Integrated life-cycle analysis is an important approach in road asset management, as it considers all stages of the asset's life cycle and incorporates sustainability aspects into decision-making processes.

To improve the efficiency and effectiveness of road asset management, various components can be integrated into a comprehensive framework. These components include data collection, condition assessment, performance modelling, and decision-making (Tee & Ekpiwhre, 2019). By integrating these components, road asset management systems can provide a systematic approach to managing assets and support effective decision-making processes.

Local roads also require specific attention in road asset management. Developing a road asset management system specifically for local roads can help address the unique challenges and requirements of these road networks. Such a system would incorporate data collection, condition assessment, performance modelling, and decision-making processes to support effective asset management practices.

The integration of Geographic Information Systems (GIS) and Building Information Modeling (BIM) can also enhance road asset management. By combining these technologies, data management, visualization, and decision-making processes can be improved, leading to more effective road asset management.

Optimizing maintenance strategies is another important aspect of road asset management. Genetic algorithms can be used to find the most cost-effective maintenance plans, considering factors such as asset condition, budget constraints, and performance objectives.

In summary, road asset management systems encompass various components and approaches, including decision support methods, life-cycle analysis, comprehensive frameworks, integration of technologies, and optimization strategies. These approaches and systems are essential for effective road asset management and can contribute to the longevity and performance of road networks.

Road asset management systems also plays a crucial role in ensuring the efficient management and maintenance of road infrastructure worldwide. These systems encompass various software and technologies that aid in data collection, analysis, decision-making, and resource allocation. This section of literature review aims to provide an overview of the world application and software/systems used for road asset management, highlighting their features, benefits, and global implementation.

In Kazakhstan, Pantuso et al. (2019) explained the Road Assets Management System (RAMS) is being implemented under the management of the Committee for

Roads. RAMS utilizes a network-level pavement management program to effectively analyse pavement condition survey data. This system enables informed decision-making regarding maintenance and rehabilitation strategies, optimizing resource allocation for road asset management.

The Intelligent Road Sign Inventory (IRSI) system Hu (2012) utilized image recognition and attribute computation from video logs to enhance road asset data collection and processing. By accurately measuring sign-to-camera distances, IRSI improves the efficiency and accuracy of road sign inventory management. This system has the potential for global application in road asset management.

Tee & Ekpiwhre (2019) showed the reliability-based preventive maintenance strategies are gaining prominence in road asset management. These strategies utilize real-time data obtained from network maintenance management systems to optimize maintenance schedules and improve the reliability of road junction systems. The application of case-based reasoning cycles enhances decision-making and resource allocation for preventive maintenance.

Chamorro & Tighe (2019) suggested a comprehensive multi-infrastructure optimization models and algorithms are being developed for transportation asset management agencies. These models consider multiple infrastructure components, such as roads and bridges, and provide maintenance and rehabilitation schedules based on cost-effectiveness and performance criteria. The implementation of these models improves the overall management of transportation assets globally.

Research on Comprehensive Multi-Infrastructure Optimization in Transportation Asset Management: The Case of Roads and Bridges Chen et al. (2019) focused on the development of a comprehensive multi-infrastructure optimization model for transportation asset management agencies. The model considers cost-effectiveness and performance criteria to generate maintenance and rehabilitation schedules. The findings demonstrate the effectiveness of the model, making it applicable to road asset management globally.

A Framework for Monitoring of Road Agency Performance in Rural Road Asset Management explained by Bopoto et al. (2019) addressed the challenges of road asset management in Africa by proposing a framework for monitoring road agency performance. The framework aims to improve performance and address persisting

issues in road asset management. The insights gained from this research can be valuable for road asset management systems in both American and African contexts.

Road asset management systems and software are essential tools for effective road infrastructure management worldwide. The examples discussed in this literature review demonstrate the global application of various systems, including RAMS, IRSI, reliability-based maintenance strategies, and comprehensive multi-infrastructure optimization. These systems contribute to improved decision-making, resource allocation, and sustainability in road asset management. As technology advances and global best practices evolve, road asset management systems will continue to play a vital role in maintaining and enhancing road infrastructure networks globally. By adopting and implementing these systems, road agencies can enhance decision-making, optimize resource allocation, and improve the overall sustainability and performance of road networks.

## **2.5 Computerised Maintenance Management System (CMMS)**

The overall concept of CMMS is explained in this section highlighting the functions of the system, benefits, and effects of CMMS and five major components within CMMS. Other implementations model of studies was also explained in this section.

### **2.5.1 Understanding the Definition, Objective and Purpose of CMMS**

A Computerized Maintenance Management System is a software tool that helps organizations efficiently manage and maintain their assets, including road infrastructure. It is designed to streamline maintenance operations, improve asset performance, and minimize downtime. The term of CMMS that have been introduced since 1980 and have been used widely since 1990s to act as an overall information system to support maintenance practices. Even though the emergence of industrial revolution 4.0 and modern technology the concept of CMMS is still relevant to be used today in any organization.

In the digital space, the computer-based operating systems, commonly referred to as computerised maintenance management systems, enable quick and effective

communication between stakeholders, facilitate improved planning, easy access to historical data, reporting and performance improvements of the maintenance function. However, success in the use of CMMSs depends on the human capacity of the users of the system. In practice, many organisations use the CMMS tool for planning, operations management, and reporting, without the aid of detailed analysis of operational information in the CMMS database. They fail to harness all the possible benefits (Petrillo et al., 2021). Some of the objectives of a 'CMMS are effective maintenance of machines, rational asset management, and consequently higher productivity of a company (Petrillo et al., 2021).

Information systems to support maintenance function are referred as Computerized Maintenance Management Systems (CMMS) (Lopes et al., 2016). CMMS is a tool to support maintenance strategy based on an information system and a set of functions that process data to produce indicators to support maintenance activities (Lopes et al., 2016).

Labib et al., (1998) believed that an available CMMS (computerised maintenance management system) is not an aim by itself, but rather a platform for decision analysis that can lead to the development of the world-class model. Many managers have relied on such systems for data collection and data analysis some for decision analysis.

Another objective of CMMS explained by Zemmouchi-Ghomari et al., (2020) is to improve data sharing and master the management of human purpose, material, or technical purpose and budgetary or financial purpose. All to improve productivity, human interventions, reporting of information, extend service of life or reduce cost of maintenance.

## **2.5.2 The Components of CMMS or Framework**

Workflow order is the operational modules that are included in CMMS for asset management, concurrently preventive maintenance management and inventory control and report management also are other components in CMMS structure or framework.

Typical CMMS software contains different modules, which enable the maintenance operatives to execute different activities. Some of the operational modules

include asset management, work order management, preventive maintenance management and inventory control and report management. Others include service management, contract management, materials management, and procurement management (Petrillo et al., 2021).

Lopes et al., (2016) listed five (5) sets of functions and application of CMMS which are:

1. Assets Management: that consists of recording all assets (or equipment) and a historical record of repairs and equipment parts list.

2. Work Orders Management: that allows setting and releasing of work orders to the maintenance technicians.

3. Preventive Maintenance Management: that supports the planning, scheduling, and control of activities.

4. Inventory control: giving access to spare parts availability.

5. Report Management: CMMS processes large amounts of data and produces performance indicators.

Lopes et al., (2016) also stated that many companies prefer to develop their own software for maintenance without relying on commercial maintenance software packages which have some weakness includes condition monitoring data analysis, equipment failure diagnosis, limited support to resource allocation and complex decision analysis support.

Zemmouchi-Ghomari et al., (2020) on the other hand, listed the common functions of CMMS software which are equipment management, maintenance management, purchasing management, personnel management, and planning, inventory management, cost management and budgeting, management of the security of the installations for the maintenance works and monitoring Key Performance Indicators (KPIs).

For the system to perform, CMMS should contain relevant maintenance documentation records, fast information access, remote data gathering for Key Performance Indicators (KPI) determination and accessibility of integration with other systems.

### **2.5.3 Benefits of CMMS Implementation**

It is stated that CMMS enables the automation of maintenance procedures in terms of communicating with maintenance units, planning, and executing maintenance operations and communicating (real time) with all relevant stakeholders (Petrillo et al., 2021).

Lopes et al., (2016) stated that the implementation of a CMMS will allow a quick and effective communication and will bring many benefits such as improved planning and scheduling. Apart from planning, CMMS will allow easy access to historical data and generations of report allowing a cost reduction associated with spare parts and maintenance activities. The use of a CMMS in the organization will also facilitate the implementation of Total Productive Maintenance (TPM) philosophy with success. While Meira et al., (2020) explained how the use of CMMS helps to increase productivity and reduce costs at a significantly 70-80% productive and 3-12% reduction of cost.

Weinker et al., (2016) emphasized a strong maintenance management with the right support of IT infrastructure. One part of maintenance management is the ability to interpret the data available and analysed the information to manage the equipment in the best possible way. To do so, the IT infrastructure to collect data must be analysed in a structured manner otherwise it cannot be effectively utilized.

Building a strong foundation for Predictive Based Maintenance (PBM) can be provided using CMMS with its higher level of data acquisition to maintenance order generation CMMS can help to direct decision making and provide a better information for asset management (Gorski et al., 2022).

### **2.5.4 Implementation Model Studied in Previous Paper**

In Petrillo et al., (2021), a benchmarking procedures method to compare against the current practices and challenge to provide the ideal method of CMMS in operation management was proposed. These help to facilitate automation of operation and help in achieving the objectives of smart maintenance. At the same time. The use of another technological advancement such as Augmented Reality (AR) was suggested by Lopes

et al., (2016) to be used for helping integration of virtual information with the real world. Lopes et al., (2016) also suggested using Failure Mode and Effect Analysis (FMEA) to develop a systemic analysis of failure occurrences. It also allows improvements in setting knowledge of the maintenance plans to reduce failures, identifying the classifications of failures and reducing time of failure diagnosis.

One of the objectives of Labib et al., (1998) was to demonstrate the practical methodology for adding value to data collected through offerings of decision analysis. Using three suggested steps of criteria analysis, decision mapping and decision support and a decision grid mapping was established. The decision-making grid shown in the case study is considered a crucial map where discussion of the performances of the worst machines are monitored based on multiple criteria, and actions are taken based on the relative position of the machines in this grid.

Many suggested the use of Analytical Hierarchy Process (AHP) as a technique for CMMS selection (Meira et al., 2020), some method evaluated functional and non-functional features according to the international standards and proposed using Fuzzy-AHP to determine which CMMS to be used which are more complex.

Gorski et al., (2022) made the proposal to automate the process of generating maintenance orders using Machine Learning (ML) and Multicriteria Decision Making (MCDM) providing automated form completion. The study was to demonstrate the concept of Smart Workflows and combine additional methods such as Analytical Hierarchy Process (AHP), PROMETHEE and reliability analysis to rank failure modes of a complex systems (Gorski et al., 2022).

Rastegari et al., (2016) also explained the use of MCDM in Maintenance Decision Making which elaborates the preventive, corrective, and breakdown maintenance in a Decision-Making Grid (DMG). Using pareto analysis, the criteria of downtime and frequency is considered and can also be substituted with Mean Time to Repair (MTTR) and Mean Time Between Failures (MTBF) (Rastegari et al.,2016).

## **2.6 Monte Carlo Simulation in Infrastructure and Maintenance Studies**

The central objective of this research is to evaluate the operational feasibility of integrating CMMS into REACT to improve maintenance responsiveness, streamline work order management, and reduce downtime across road electrical assets in Selangor. Since PWD has not yet implemented CMMS, direct empirical measurement of improvements is not possible. Simulation therefore provides a structured and ethical approach to estimating potential gains without disrupting existing operations. In this study Monte Carlo Simulation is the ideal choice of distribution simulation.

### **2.6.1 Monte Carlo Simulation in Infrastructure and Asset Management Research**

Monte Carlo Simulation (MCS) has become an essential tool in infrastructure and asset management research, especially for applications involving complex systems with high uncertainty. The fundamental advantage of MCS is its capacity to use repeated random sampling to understand the variability inherent in asset performance and maintenance scenarios (Jamroz & Williams, 2020). The uncertainties associated with infrastructure components, such as road electrical assets, require a probabilistic approach due to the unpredictable nature of factors that influence system failures and maintenance responses (Sander et al., 2006). For instance, the ability of MCS to facilitate "what-if" scenarios and assess maintenance strategies in uncertain conditions is crucial for examining the integration of Computerised Maintenance Management Systems (CMMS) into frameworks like REACT in Selangor (Shaw-Williams et al., 2018).

The implementation of MCS in evaluating road electrical assets, such as traffic lights and street illumination, is enhanced by acknowledging the stochastic nature of failure events. Research indicates that failure rates in these systems are significantly influenced by external factors, such as weather conditions, necessitating probabilistic models over deterministic ones (Seen et al., 2023). MCS has been shown to improve predictive capabilities in maintenance planning, particularly in settings with uncertainty surrounding failure rates and response times (Neumann et al., 2019). This exploration

aligns with our study's aim to assess the likely benefits of integrating CMMS and REACT systems.

Furthermore, MCS can effectively model historical complaint data specific to regional contexts, improving the assessment of operational responsiveness under varying conditions. Research has demonstrated that the application of MCS in predictive maintenance can lead to substantial operational improvements (Arboleda & Abraham, 2006). These findings support the case for using MCS in our feasibility study, particularly for forecasting reductions in complaint resolution times prior to deploying a CMMS (Bahoo Torood et al., 2020).

### **2.6.2 Poisson Distribution and Its Relevance to Maintenance Modelling**

The Poisson distribution is well-regarded as an effective statistical tool in maintenance modeling, especially for events that occur randomly and independently over time. This is particularly relevant in road electrical asset management, where failures often arise due to the stochastic influence of external factors. Studies have indicated that maintenance-related events frequently conform to Poisson characteristics, making the Poisson distribution valuable for accurately modeling failure patterns in infrastructure systems (BahooTorood et al., 2021).

Empirical support for the application of the Poisson distribution is provided by research confirming that electrical failures in roadways typically follow a Poisson arrival process (Okeola et al., 2025). This indicates that the events triggering these failures occur independently, which solidifies the Poisson distribution's relevance for analyzing road electrical failures. Integrating Poisson distribution into the MCS framework enhances modeling accuracy by adequately portraying the time between failures as an exponential distribution, consistent with the randomness of maintenance complaints (Cho et al., 2012). This solid statistical basis addresses evaluators' concerns regarding the robustness of the statistical assumptions in the simulations and informs decision-making processes in maintenance planning (Khan & Haddara, 2004).

### **2.6.3 Iterations of Simulation**

Setting the appropriate number of iterations in MCS involves balancing precision needs with study complexity and objectives. The literature reveals considerable variation in the number of iterations selected based on the specific requirements of different fields (Zuniga-Garcia et al., 2018). For instance, while high precision in probability estimates often necessitates hundreds or thousands of iterations, many studies focused on general trends can succeed with fewer iterations (Lara-Molina et al., 2020). This flexibility is crucial for the proposed integration assessment, allowing a customized approach that aligns with research objectives while effectively utilizing MCS's computational power for meaningful insights.

In asset management, researchers assert that study goals should dictate iteration counts, emphasizing exploration of overall operational patterns rather than strict adherence to statistical norms (Adegbola, 2022). Thus, a pragmatic iteration strategy in the current feasibility study aligns with established practices in MCS and supports the dynamic exploration of maintenance strategies within the REACT framework (Zavala et al., 2025).

## **2.7 Thematic Analysis of Focus Group Discussion (FGD)**

### **2.7.1 Concept and Purpose of Thematic Analysis**

Thematic analysis is a widely used qualitative method that allows researchers to identify, organize, and interpret patterns of meaning within data. It is flexible, making it applicable across various disciplines such as healthcare, education, and public sector research, which often focus on human experiences, behaviors, and perceptions. As described by Braun and Clarke (2021), thematic analysis involves a systematic approach to analyzing qualitative data and generating themes that represent the shared experiences of participants. The method is particularly useful for studies that aim to explore the meanings individuals attach to their lived experiences.

In the context of asset management and system integration, thematic analysis offers valuable insights beyond what can be captured through quantitative metrics alone. For instance, Stockton et al. (2023) used thematic analysis to explore how individuals' perceptions of technology and system integration impact their engagement and readiness for digital transformation. Similarly, Pretorius et al. (2011) applied thematic analysis to examine the emotional and relational aspects of sensitive topics, showing how this method can capture complex, multi-dimensional factors that influence stakeholder decisions and behaviors. By applying thematic analysis, this study can uncover the underlying attitudes and concerns of PWD Selangor and REACT operators regarding CMMS integration

### **2.7.2 Thematic Analysis Process and Coding Framework Using ATLAS.ti**

The thematic analysis process used in this study follows the six-phase framework outlined by Braun and Clarke (2021), which ensures a rigorous and transparent approach to data analysis. These phases include familiarization with the data, generating initial codes, searching for themes, reviewing themes, defining and naming themes, and producing a final report. This systematic approach enables researchers to stay grounded in the data while identifying patterns that are meaningful and relevant to the research objectives.

To facilitate the coding and theme development, ATLAS.ti was employed as the primary tool for data management and visualization. The software allowed for the efficient organization of data, aiding in the identification and comparison of recurring patterns across the focus group discussions. According to Stockton et al. (2023), such qualitative software enhances the consistency and transparency of the coding process, providing a clear audit trail and ensuring that findings are not subject to researcher bias. In this study, a hybrid coding strategy was employed, combining both deductive codes (e.g., "workflow challenges" and "communication structure") based on the research questions, and inductive codes that emerged naturally from the data. This approach aligns with the practices used by Cowan-Dickie et al. (2024) in their study of patient experiences with digital health tools.

### **2.7.3 Application of Thematic Insights to the Feasibility Assessment**

The themes identified through thematic analysis provided valuable insights that were integral to assessing the feasibility of CMMS integration with REACT. Participants highlighted the need for better visibility of asset status, improved coordination among teams, and more structured workflows. These insights directly align with the strengths of CMMS platforms, which are designed to streamline operations and improve data management. As noted by Stockton et al. (2023), the integration of digital tools can lead to significant improvements in operational efficiency, but only when there is buy-in from stakeholders and alignment with their expectations and needs.

At the same time, thematic analysis revealed concerns about data quality and the potential for increased workload due to system integration. These issues echo findings from broader research on digital transformation, where the lack of adequate data readiness and interoperability often hinders successful implementation (Pretorius et al., 2011). The themes surrounding human readiness and organizational culture emphasized the importance of providing adequate training, clear role definitions, and ongoing support for staff members. These insights suggest that, while CMMS integration has the potential to improve operational performance, its success will depend on addressing these human and organizational factors. The findings from this study complement

quantitative simulation results, providing a holistic understanding of the barriers and facilitators to CMMS adoption.

## 2.8 Summary

Based on the literature review, electrical assets fall under the classification of electronic furniture which are important to the safety of road users. A unified system such as REACT monitors the asset real-time but without enough maintenance information it is inefficient towards maintenance practices and asset reliability. Preventive Based Maintenance is more reliable than Corrective Based Maintenance which repairing of assets is acted before failure. Hence, it is important to adopt a proper Computerised Maintenance Management System (CMMS) into the existing REACT monitoring system. A feasibility study of implementing CMMS will be beneficial towards the overall functioning of the monitoring and management system.

The findings make it clear that assets such as traffic lights and streetlighting require more than just monitoring; they need a structured maintenance approach to ensure reliability, reduce downtime, and maintain public safety. Although REACT provides real-time visibility, it does not support critical maintenance functions such as preventive scheduling, work order tracking, or performance monitoring. This creates an evident operational gap for agencies like PWD Selangor.

The literature also shows that CMMS is widely recognised for improving maintenance performance, enabling better decision-making, and supporting key indicators like MTTR, MTBF, and asset failure trends. Studies also highlight the value of integrating CMMS with recognised maintenance frameworks such as TPM and RCM. However, there is still no research that specifically addresses how CMMS can be integrated with Malaysia's existing monitoring platforms, especially one as large scale as REACT. This gap strengthens the need for a unified approach. The review also emphasises the importance of simulation methods particularly Monte Carlo Simulation in forecasting asset failures and evaluating maintenance strategies. These methods are proven in infrastructure research but have not been applied in the context of CMMS for road electrical assets in Malaysia.

Overall, the chapter clearly identifies a missing link between monitoring and maintenance functions in current practice. There is no existing framework that combines REACT's monitoring strengths with the structured maintenance capabilities of a CMMS. This gap justifies the development of an integrated CMMS to REACT

model and supports the use of simulation and stakeholder input in the methodology presented in the following chapters.

## CHAPTER 3

### RESEARCH METHODOLOGY

#### **3.1 Introduction**

This chapter explains the research methodology used to evaluate the feasibility of integrating a Computerised Maintenance Management System (CMMS) into the existing Road Electrical Asset Control and Telemetry (REACT) system. Because PWD Selangor has not implemented a CMMS before, direct measurement of improvements is not possible. Therefore, the study applies a methodology that combines both quantitative simulation and qualitative stakeholder validation to assess the potential operational benefits.

The research adopts a mixed methods design. The quantitative component uses Monte Carlo Simulation (MCS) to model the expected changes in complaint resolution times when CMMS features are applied to road electrical asset operations. This allows the study to estimate improvements in scenarios that cannot be tested in real operations. The qualitative component consists of a Focus Group Discussion (FGD) involving key stakeholders from PWD Selangor. Their insights help validate the simulation results, interpret operational readiness, and identify practical challenges related to CMMS implementation. By integrating both simulation and stakeholder feedback, this methodology provides a balanced evaluation of technical feasibility, operational impact, and organisational preparedness for CMMS-REACT integration.

#### **3.2 Research Flow**

Understanding the Study Settings in-depth of the Public Work Department and the Unified Electrical Monitoring System will establish the research context and parameters. Thus, allowing the system characteristics to be investigated and outlining the key attributes of features in the unified system.

First objective or stages of data methodology is to examine the maintenance documents required for road electrical assets. By examining the current data collected from the unified system, the study can understand the current maintenance approach

and the maintenance information required to do maintenance. Scrutinizing the data obtained from the Unified Electrical Monitoring System in comparison with maintenance practices will evaluate its quality and recognizing its effectiveness.

Second stage is to propose an implementation model of CMMS into the unified system. Analysing CMMS adaptation can employ analytical techniques to assess the feasibility and compatibility of CMMS within the unified system. With the implementation of CMMS into the unified system the effectiveness of time and management is recognized and recorded to compare with the current maintenance management practices.

During this stages, Data collection & variable Identification will help data gathering from the current system and proposed CMMS model which are crucial for simulation. These variables can ease the feasibility study process or the new implementation of CMMS into the unified system.

Finally, the study supports rigorous evaluation by representatives from Public Work Department (PWD) subjecting their criteria and feedback can add further input to the proposed system. The research flow is summarised in Figure 3.1.

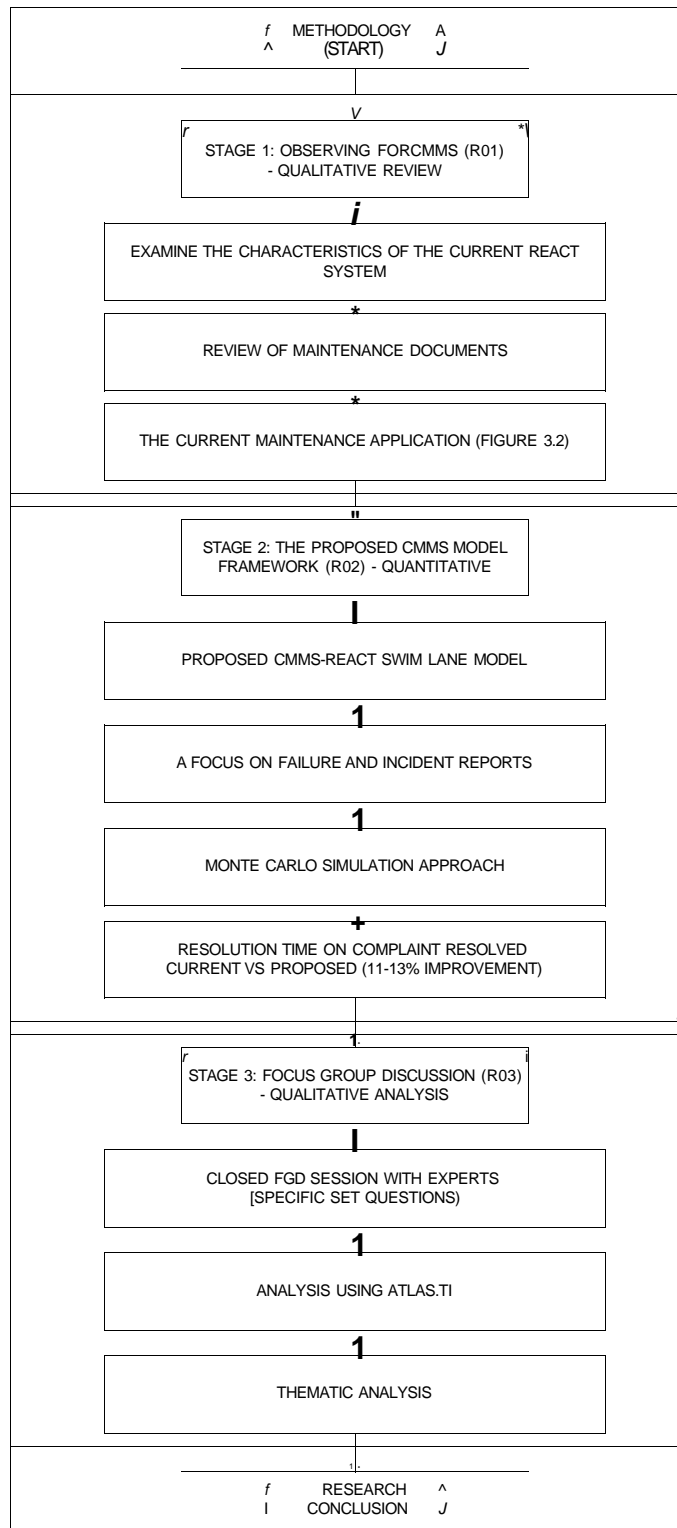


Figure 3.1 The Research Flow chart

### 3.3 Research Study Settings

Data collection in this study focuses on obtaining accurate operational information from the REACT system and validating it with PWD Selangor. The collected data forms the foundation for the simulation model and supports the qualitative evaluation carried out later through the Focus Group Discussion (FGD). These inputs allow the simulation to estimate how CMMS integration may influence operational outcomes such as resolution time and maintenance efficiency. The study settings were listed and described in Table 3.1.

Table 3.1  
Research Study Settings

<b>Study Settings</b>	<b>Description</b>
<b>Maintenance Practices Comparison</b>	The study compares the differences Focuses on the Road Electrical Asset Control & Telemetry (REACT) system used exclusively by the PWD of Selangor and the normal maintenance practices without the system. This will provide the existing view of maintenance practices by PWD.
<b>Electrical Asset Monitoring</b>	The research system primarily oversees traffic lights, street lighting critical for road safety and infrastructure management while excluding CCTV systems. Maintenance documents collected are specific for maintaining traffic lights and street lighting.
<b>Exclusion of Underground Cable Management</b>	Even though, underground cables are part of the electrical system environment, this study excludes the monitoring and management of underground cable systems, concentrating on above-ground electrical assets.
<b>Data Accessibility Duration</b>	The collected documents to review were taken from January 2021 to December 2023.

### 3.3.1 Examining the Characteristics of Unified System (Current System)

The current system of REACT is focussing on real-time monitoring of streetlights and traffic lights in a centralized platform. Asset management information is available but only into asset registration without proper maintenance information. Table 3.1 shows the data elements to review from REACT or from the conventional maintenance practices. Determining the required maintenance practices for each type of assets can help to develop a proper implementation of CMMS. The data extracted consisted of structured fields, semi-structured fields, and categorical fields. These attributes were necessary to model complaint behaviour accurately in the simulation.

Table 3.2  
Data Elements of REACT and Maintenance Information

<b>Data Category</b>	<b>Data Elements</b>	<b>Importance for Maintenance</b>	<b>Implemented / Practiced (System Intergrator)</b>	<b>Implemented / Practiced (System Owner)</b>
<b>Asset Identification</b>	Asset name or description	Helps in quick asset identification during maintenance.		
	Unique asset identifier or serial number	Ensures precise tracking of individual assets.		
	Asset location (geographical or within a facility)	Enables maintenance teams to locate assets efficiently.		
	Asset category or type (e.g., equipment, machinery, vehicles)	Aids in organizing maintenance tasks by asset type.		
<b>Asset Specifications</b>	Technical specifications and details	Provides insights into asset capabilities and requirements.		
	Manufacturer information	Helps in sourcing parts and expertise for repairs.		
	Installation date	Determines the asset's age and potential maintenance needs.		

	Expected service life	Indicates when major overhauls or replacements may be required.
<b>Maintenance History</b>	Records of past maintenance and repairs	Offers insights into recurring issues and preventive measures.
	Maintenance schedules and plans	Guides future maintenance and inspections.
<b>Warranty and Documentation</b>	Warranty information	Ensures compliance with warranty terms and conditions.
	Manuals and documentation related to the asset	Assists in proper maintenance and troubleshooting.
<b>Asset Condition</b>	Current condition or status of the asset (New or Spare)	Provides a snapshot of immediate maintenance requirements.
	Inspection reports	Records observations for potential corrective actions.
<b>Asset Criticality</b>	Importance or criticality of the Asset to operations (minimum lifespan estimation)	Guides prioritization of maintenance efforts.
<b>Spare Parts and Inventory</b>	List of spare parts and associated inventory	Facilitates quick part replacement during maintenance.
	Ordering and restocking details	Maintains efficient inventory management for minimal downtime.
<b>Maintenance Tasks</b>	List of routine maintenance tasks required	Forms the basis for maintenance planning and schedules.
	Frequency and procedures for maintenance	Guides technicians in performing maintenance tasks correctly.

<b>Maintenance Contacts</b>	Personnel responsible for asset maintenance Contact information for maintenance providers	Ensures accountability and easy contact for maintenance teams. Facilitates external service provider coordination.
<b>Failure and Incident Reports</b>	Records of asset failures, breakdowns, or incidents	Offers insights into asset weaknesses and areas for improvement.

A system review by system owner (PWD of Selangor) and system integrator (Loranet Technologies PLT) are needed to collect the maintenance documentation and elements used in the organization to understand wholly the required maintenance for road electrical assets. Understanding these requirements can help further the feasibility study.

### 3.3.2 Review of Maintenance Documents

In this method, the research suggests doing a document collection versus time needed to response of breakdowns. The maintenance document information registration must be separated into three stages which is initial installation, routine maintenance or preventive maintenance & breakdown or corrective maintenance. The number of documents to fill in versus time of response is collected. Table 3.3 explains the data collection intention table, briefly describing the expected data to be collected.

Table 3.3  
Data Collection Intention Table

<b>Aspect</b>	<b>Document Review</b>
Data Source	Asset Registration, Maintenance Documents, Maintenance Reports
Objective	Number of Documents
Research Focus	Document relevance, usability, gaps & Time of response
Data Extraction	Number of Documents to Fill or Time of Response

The applied documents within areas of PWD of Selangor will help to give more

perspective on the maintenance aspect and system overview versus the time of response to do maintenance. The secondary data to be collected was estimated from January 2021 until December 2023.

Upon asset registration, number of pertinent maintenance information is documented. Subsequently, for preventive maintenance activities such as adhering to maintenance schedules or conducting routine maintenance checks, the requisite forms are analysed, and the response time to maintenance tasks is documented. This process aligns with maintenance planning principles aimed at breakdowns by ensuring timely interventions. In the event of breakdowns or failures, the number of maintenance forms or documentation required is logged, together with the time taken to rectify the issue.

Document that can be reviewed from suppliers and PWD can include detailed guidance on repair and troubleshooting procedures, maintenance schedules and plans that outline regular and preventive maintenance tasks, factory assessment test to document observations and identify potential corrective actions, warranty information to ensure compliance with warranty terms, inventory control data for efficient spare parts management, contact information for internal service provider's coordination, and failure reports for understanding asset weaknesses and opportunities for improvement.

To conclude, the data collection strategy is to support the first research objective which is to determine the required maintenance documents for road electrical assets maintenance practices. Both participants from suppliers and PWD will be required to give extensive information, experience, or evidence to support the analysis of this paper.

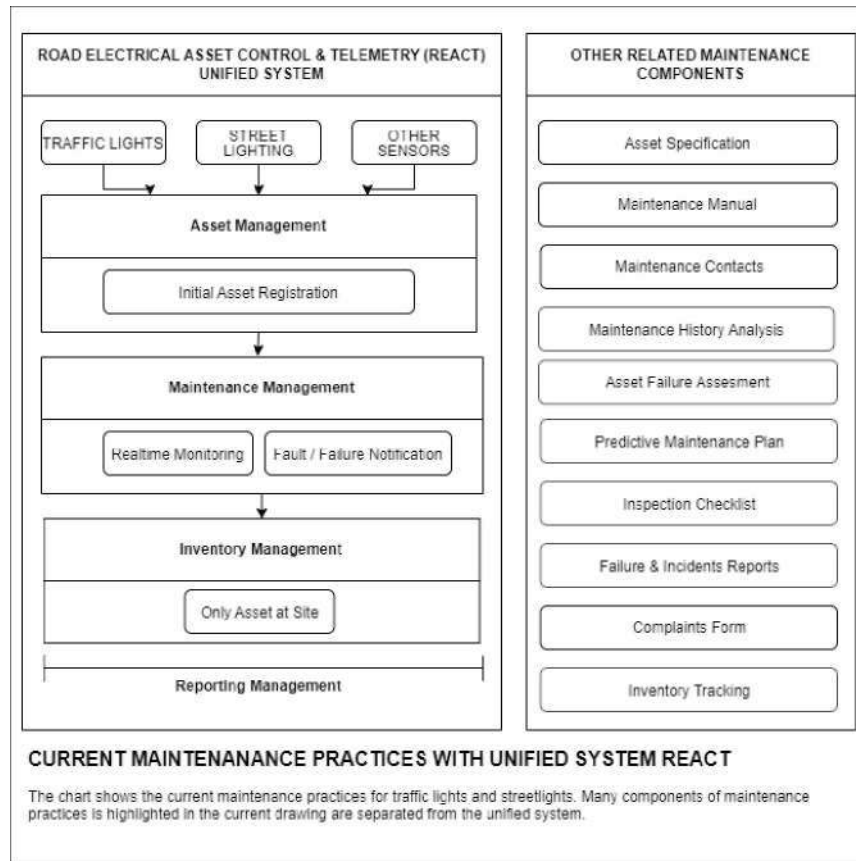


Figure 3.2 The Current Maintenance Application

### 3.4 The Proposed CMMS Model and Framework

Collection data on the maintenance practices of road electrical assets is crucial including historical maintenance records, asset characteristics, maintenance schedules and the ability to structure the process into a framework or workflow is demanded to develop a proper CMMS system. This can result in the critical maintenance needs and areas for improvement as well as identifying its maintenance trends. Hence, initial asset installation data must be recorded with maintenance values to help CMMS work as effectively as possible. In this feasibility study, the number of documentation and the time of response towards maintenance is a weightage in the implementation of CMMS.

#### 3.4.1 Observing for CMMS

CMMS Framework for a Unified System also must consider supplier brands which is an important key in the system. Maintenance information regarding asset

tailored to brands must be included in the CMMS values as it will help problem solving and future maintenance. Develop a comprehensive CMMS model tailored to road electrical assets include features for preventive and corrective maintenance, work order management, inventory control, asset registration, and reporting as describe in the literature about CMMS general characteristics. Features of development of the CMMS are shown in Table 3.4 as follows:

Table 3.4  
Key Components in a CMMS Implementation and Its Importance

<b>Feature</b>	<b>Description</b>	<b>Key Components</b>	<b>Importance</b>
<b>Assets Management</b>	Comprehensive asset tracking and recording of equipment, including a historical log of repairs, maintenance history, and equipment parts list.	<ul style="list-style-type: none"> <li>- Asset registration</li> <li>- Maintenance history</li> <li>- Equipment parts list</li> <li>- Asset categorization</li> </ul>	Ensures asset traceability, history, and efficient maintenance planning.
<b>Work Orders Management</b>	Facilitates the creation, assignment, and management of work orders for maintenance or repair tasks. It ensures that maintenance technicians receive the necessary information to perform tasks efficiently.	<ul style="list-style-type: none"> <li>- Work order creation</li> <li>- Assignment to technicians</li> <li>- Work order tracking</li> <li>- Priority levels</li> <li>- Scheduled time and date</li> </ul>	Enables organized and timely maintenance activities, reducing downtime.
<b>Preventive Maintenance Management</b>	Supports the scheduling, planning, and control of preventive maintenance activities based on predefined criteria. This feature ensures that assets receive regular maintenance to prevent breakdowns and extend their lifespan.	<ul style="list-style-type: none"> <li>- Maintenance scheduling - Task checklist</li> <li>- Frequency setting</li> <li>- Asset identification</li> <li>- Performance tracking</li> </ul>	Enhances asset reliability, reduces unscheduled maintenance, and prolongs asset life.

<b>Inventory Control</b>	Manages the availability of spare parts and materials needed for maintenance tasks. It tracks inventory levels, reorders supplies, and manages supplier information.	<ul style="list-style-type: none"> <li>- Inventory tracking</li> <li>- Reorder point setting</li> <li>- Supplier data</li> <li>- Cost management</li> <li>- Materials availability</li> </ul>	Ensures that required parts are readily available, reducing maintenance delays.
<b>Report Management</b>	The CMMS processes a vast amount of data to generate performance indicators, maintenance history reports, and compliance reports. These reports offer valuable insights for decision-making and regulatory compliance.	<ul style="list-style-type: none"> <li>- Report generation</li> <li>- Custom report parameters</li> <li>- Data analysis tools</li> <li>- Compliance tracking</li> <li>- Performance indicators</li> </ul>	Provides data-driven insights for making informed decisions and maintaining regulatory compliance.

Following 5 major components of CMMS guided in literature review which includes Work Order management, Asset Management, Maintenance Management, Inventory Management and Reporting Management, the Swim Lane Model on CMMS features was developed to meet the needs of the unified system. Figure 3.3 describes the full features of CMMS which could be implemented in the unified system.

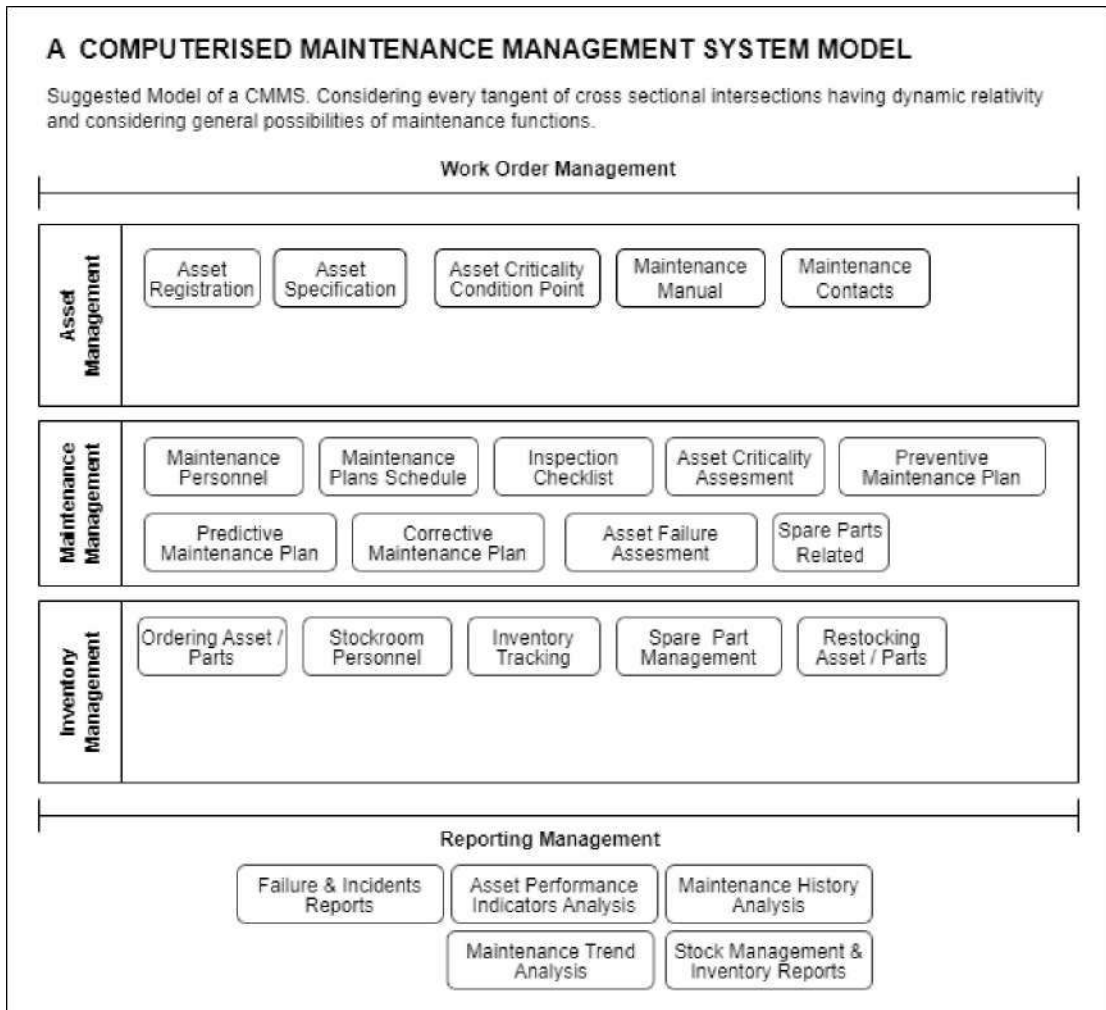


Figure 3.3 Swim Lane Model of CMMS Implementation

The importance of this model development is to easily visualize and positioning each key components of CMMS parameters on its dedicated lane. Relativity of each component is impermissible due to the generations of reporting and analysis. By creating a visual representation of how CMMS features interact and influence the workflow and decision-making processes with the unified system, a feasibility study of implementation can be made. Figure 3.4 shows the drawing of a Unified system with the integration of CMMS and its components. The green coloured boxes are what potentially feasible options of study because it is the first component in the work flow order based on its lane. In this research Failure and Incident reports are then chose to further study in a proper simulation setup.

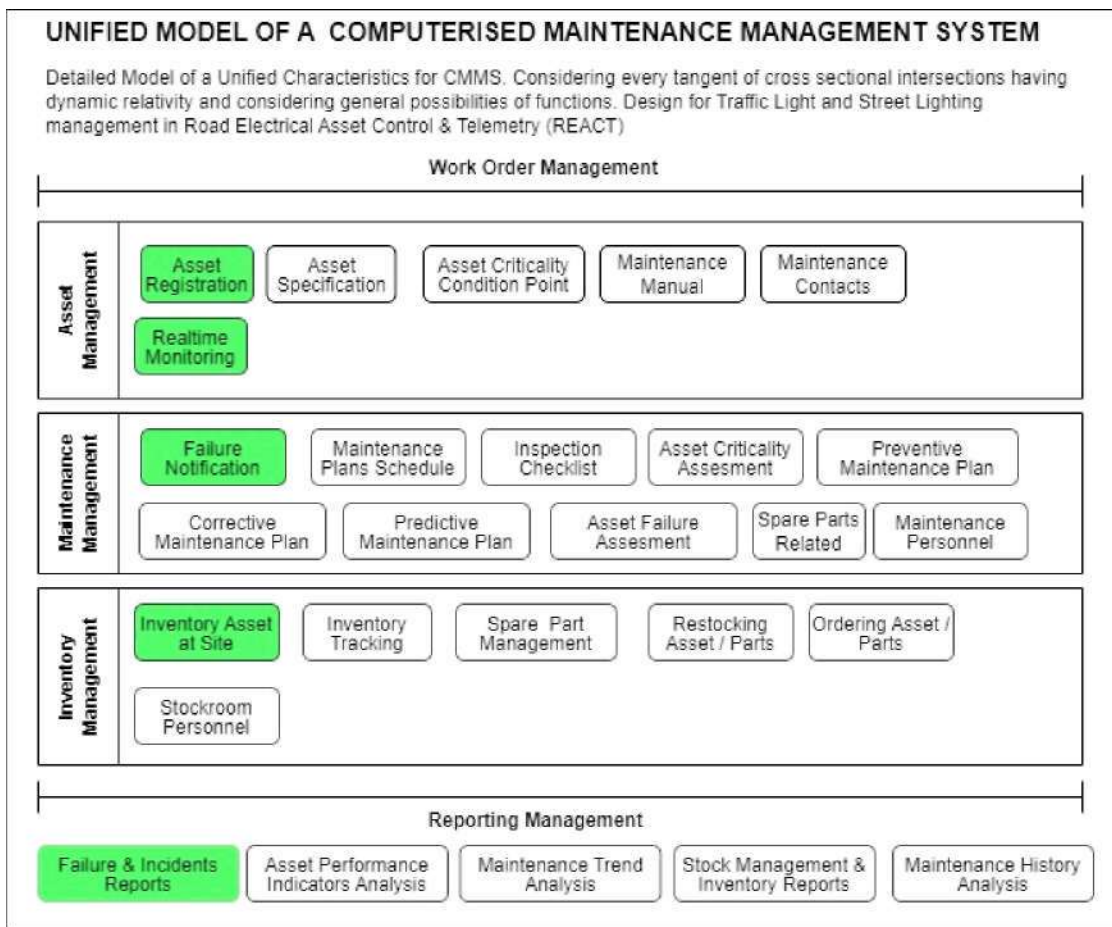


Figure 3.4 Proposed Unified System with the Intergration of CMMS

### 3.4.2 Systems for Failure and Incident Reports

From various factors and intersections of the CMMS shown in the proposed unified system, only Failure and Incident reports are suitable to be analysed in this study. The current practice of a complaint record and management system is analysed and understanding the process failure reports without CMMS can give space for the current practice to be reviewed. From figure 3.5, a brief overview of the complaint report process is shown where 7 steps is needed prior to complaint and failure records.

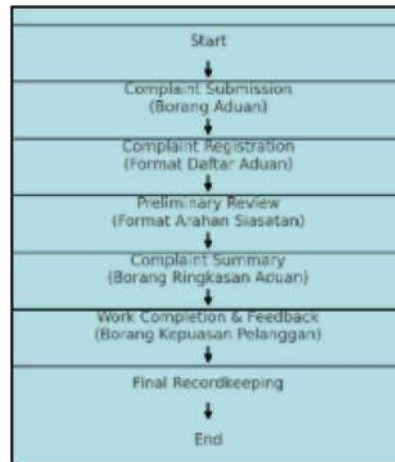


Figure 3.5 The Flow Chart of a Complaint Registration without CMMS

From another straightforward perspective, the complaints start at registration of Complaint Form, then the issues will move to Preliminary Review and Action of Inspection before work of maintenance is completed then the completion of work and feedback form. The process being independence without knowing the historical condition records and are not computerised can give a lag time in maintenance works and complaint management.

PWD itself, complaint process has three different constituents, at Federal Level, State Level and District Level and this hierarchy itself may contribute to the inefficiency of failure and breakdown management. To have CMMS implemented a streamlined approach with linked overall access need to be considered for a faster response in maintenance. A unified system which links this process will make complaint process much more effective.

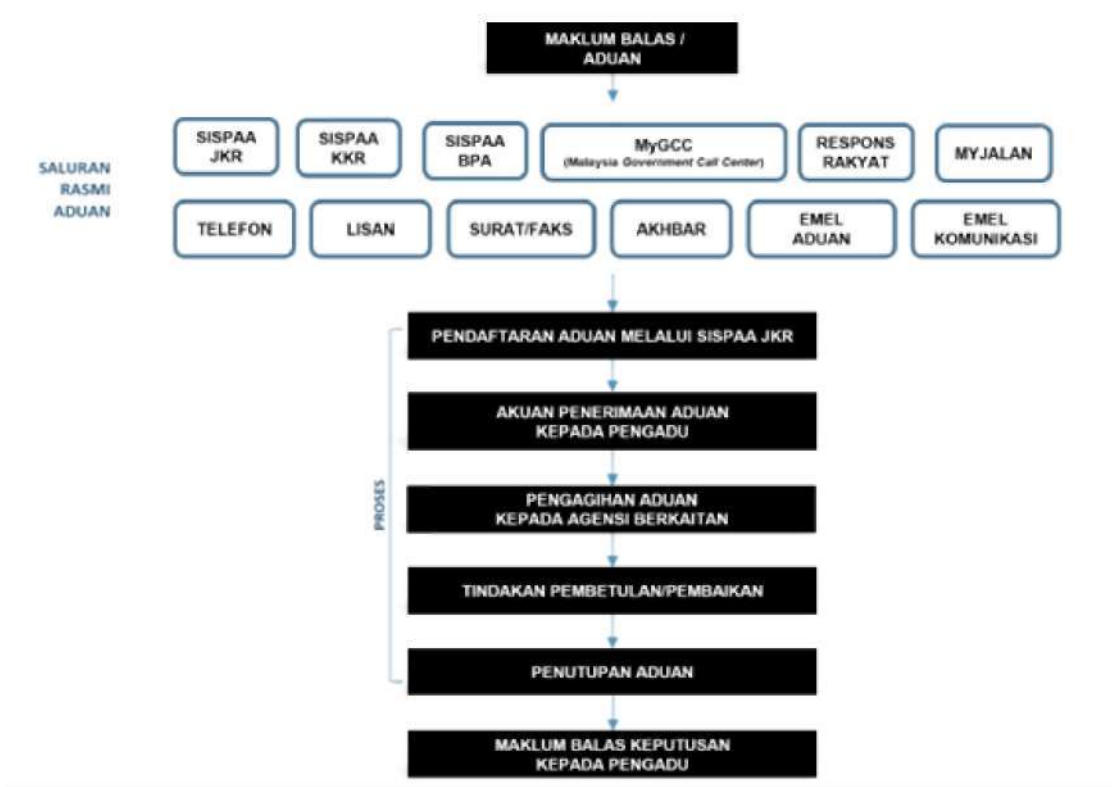


Figure 3.6 The Work Flow Chart of a Public Complaint Registration

Every complaint registered by customer or user will all be recorded in public complaint management system named SISPAAs (Sistem Pengurusan Aduan Awam) as shown in Figure 3.6. Before repair works or action is taken, a complain registry and process need to be filled by customer then verified by an officer before passes to the related agency. At this stage alone 2 or 3 personnel are reviewing the issue before passing it to next relatable agency or department.

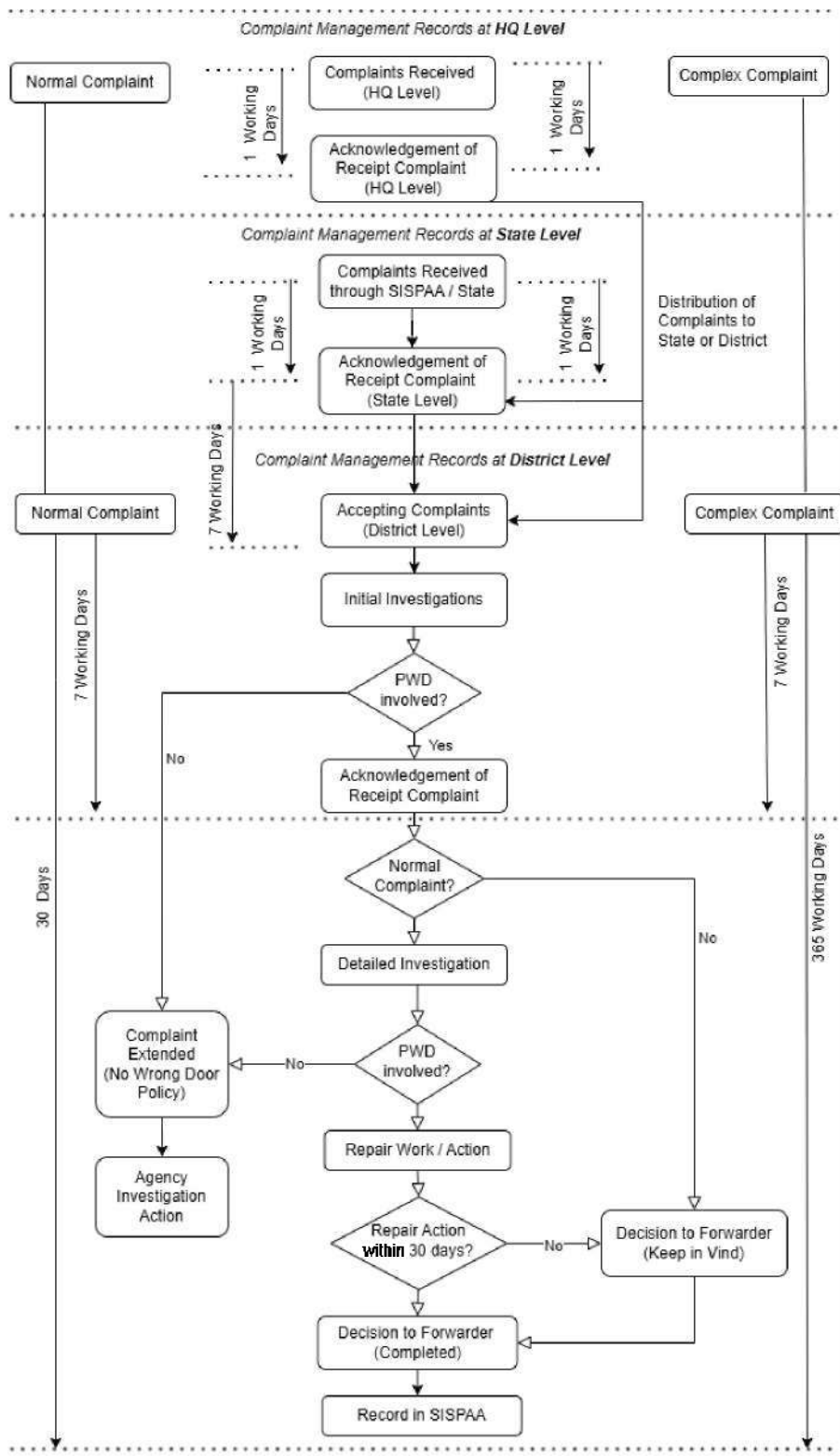


Figure 3.7 The Summary Flow Chart of a Public Complaint Registration

From Figure 3.7 there are similarities to highlight which are the complaint receipt statement, issues that are not related to the agency or the no wrong door policy,

and the forms to be recorded. Each receipt statement was filled by customers before acknowledging by officers which then proceed for inspection.

At Federal level, issue will only be pass on to respective states or district, then detailed inspection is made at district level before the 30-day repair works and considered completed or recorded. This redundancy of channels and hierarchies lengthen the process of issues to be resolved to customers. From receiving complaints to resolving complaints already involve many personnel from different levels of organisation.

To position Failure and Breakdown management of CMMS with the existing complaint management is to remove repetition, reduce hierarchies and have access or link management between the process.

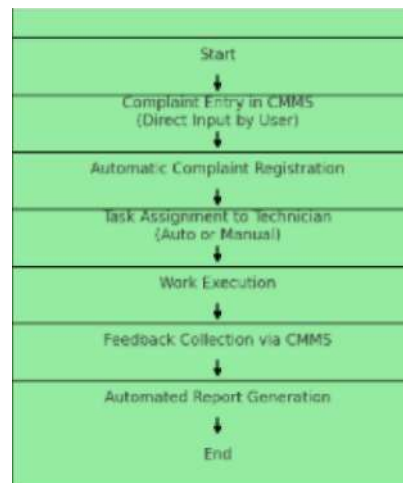


Figure 3.8 The Flow Chart of a Complaint Registration with CMMS

Figure 3.8 above is Complaint handling process with CMMS demonstrates the workflow facilitated by CMMS, clearing complexity and save time. A little automation on complaint registration and task assignment will result in a faster work action or repair works. Additional benefit to using CMMS is history repairs, inventory management or expected breakdowns can also provide a faster response answer to customers.

### 3.5 Data Collection & Simulation

To evaluate the feasibility and potential benefits of implementing a Computerised Maintenance Management System (CMMS), a simulation-based

approach was employed using historical failure and breakdown data. The primary focus of this simulation is to assess the effectiveness of response time—measured by the number of days required to resolve complaints—before and after CMMS implementation.

A structured Monte Carlo Simulation was chosen due to its ability to model uncertainty and variability in complaint occurrences, severity levels, and resolution timelines. The simulation enables multiple iterations based on historical data to estimate average complaint resolution performance and to compare outcomes across different operational scenarios.

By comparing complaint resolution durations under the current (pre-CMMS) and proposed (post-CMMS) workflows, the model supports Research Objective 2: "To evaluate the feasibility of CMMS implementation for road electrical asset maintenance based on response time improvement."

As shown in Figure 3.7, the traditional public complaint workflow involves multiple hierarchical approval steps. In contrast, the CMMS-enabled process as illustrated in Figure 3.8 reduces the number of steps by integrating automated registration, direct assignment, and access to historical maintenance records. This structural simplification is expected to shorten the complaint lifecycle.

### **Simulation Variables & Data Parameters**

The process of simulating Monte Carlo on the present system to the proposed process Flow are shown in figure 3.9

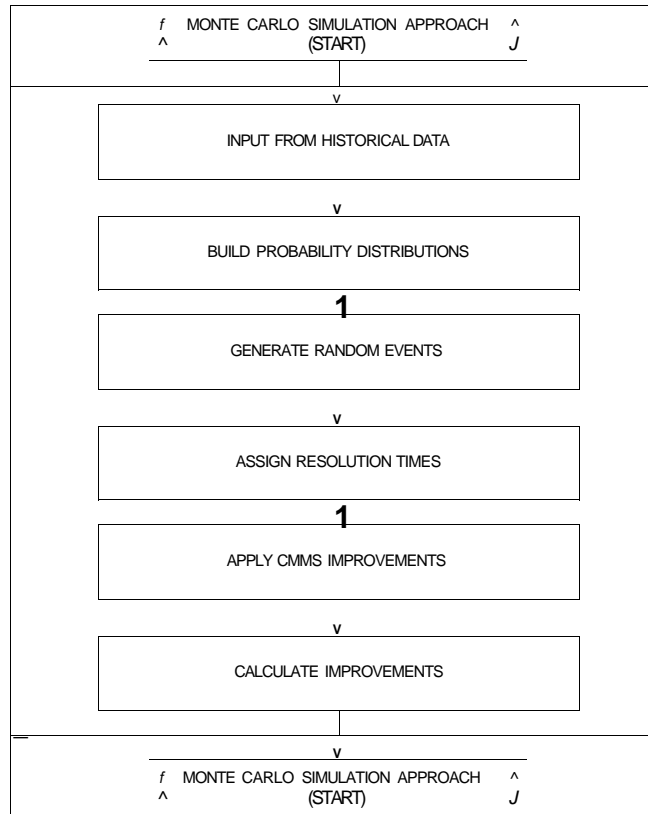


Figure 3.9 Monte Carlo Simulation Process in Complaint and Incident Reports

Monte Carlo simulation is particularly suitable for this study because the ability to modelled random variables and quantifying improvement:

- **Uncertainty Modelling:** It enables the simulation of stochastic processes, where the outcome depends on several random variables. In this case, the occurrence and severity of complaints are modelled probabilistically.
- **Quantifying Improvements:** By comparing the resolution times before and after CMMS implementation, Monte Carlo simulation allows for the quantification of improvements in operational efficiency.'

To conduct the simulation, three critical variables were identified based on historical complaint data and presented in the format of probability and random number.

#### Variable 1: Probability of Complaints on a Given Day

This variable represents the probability that complaints will be reported on any given day. The probability distribution for complaint occurrence was calculated based on historical data from 2023, which provided the foundation for simulating complaint occurrence.

### Variable 2: Number of Complaints per Day

Once a complaint is detected, the simulation determines the number of complaints expected on each day. This is crucial for estimating the workload and resource allocation necessary for resolving complaints on any given day.

### Variable 3: Severity of Complaints

Complaints are categorized into five severity levels: Insignificant, Minor, Moderate, Major, and Critical. The severity of each complaint determines the time required for its resolution, with higher-severity complaints requiring more time and resources.

These variables were modelled using probability distributions based on the complaint data collected, ensuring that the simulation reflects realistic patterns of complaint occurrences and resolution times.

### Simulation Process Summary: Step-by-Step Execution

#### A. Data Collection and Pre-Processing

The simulation begins by collecting historical complaint data from the Public Works Department (PWD) of Selangor for the year 2023, focusing specifically on electrical complaints in the Petaling district. The key data collected includes:

- Total number of complaints recorded each month.
- Severity distribution across complaints.
- Average resolution times for each severity level.

This data is analyzed to generate probability distributions for the three critical variables used in the simulation: complaint occurrence, number of complaints per day, and severity level.

#### B. Random Number Generation

The simulation utilizes random number generation to model the occurrence and characteristics of complaints. Using Excel's `RAND()` and `RANDBETWEEN()` functions:

- Complaint occurrence: A random number is generated to determine whether a complaint occurs on a given day, based on the daily probability distribution.

- Number of complaints per day: Once a complaint is registered, the number of complaints for that day is determined using a random selection from the daily distribution.
- Severity of complaints: Each complaint is assigned a severity level based on random number generation, using the severity distribution derived from historical data.

### C. Simulating Complaint Resolution Times

The time to resolve complaints is calculated based on the severity level of each complaint:

- Before CMMS: Resolution times are based on historical averages for each severity level from the current manual system.
- With CMMS: The simulation assumes that CMMS reduces the resolution time by a fixed percentage, reflecting expected improvements due to automation of work orders, better prioritization, and real-time tracking.

The total resolution time for all complaints on a given day is then calculated by summing the resolution times for each severity level.

### D. Repetition of the Simulation (10 Iterations)

The simulation is executed for 10 separate iterations for each month, simulating the complaint handling process over the entire month of January. Each iteration uses the randomly generated values for complaint occurrence, number of complaints, and severity to model the complaint handling process for the month.

For each iteration, the total resolution time is calculated for both the current system and the CMMS-enhanced system. The results from the 10 iterations are averaged to provide a reliable estimate of resolution times for both systems.

### E. Statistical Analysis

After completing the simulation, the mean resolution time and standard deviation of resolution times are calculated for both the pre-CMMS and post-CMMS systems. Standard deviation is crucial in measuring the variability of resolution times.

A lower standard deviation post-CMMS indicates that the resolution process is more predictable and consistent, suggesting improved system reliability with CMMS.

#### F. Comparison of Pre- and Post-CMMS Results

Finally, the average resolution times for both systems are compared. The improvement percentage in resolution time is calculated using the formula:

$$\text{Improvement (\%)}: \left( \frac{rd_{initial} - rd_{CMMS}}{rd_{initial}} \right) \times 100\% \quad (3.1)$$

This comparison provides a clear indication of the efficiency gains resulting from CMMS implementation, demonstrating its effectiveness in improving complaint resolution.

The simulation method utilizes historical complaint records categorized by severity and integrates Monte Carlo Simulation to iterate the data before and after CMMS implementation. The key variables used in this study are show in Table 3.5.

Table 3.5  
Key Variables in Monte Carlo Simulation

Variable	Description
<b>Existence of Complaints in a Day</b>	Determines whether complaints are reported on a given day by analyzing historical trends and probabilities based on previous complaints.
<b>Number of Complaints per Day</b>	If complaints are present, the simulation predicts the expected number of complaints based on historical data.
<b>Severity Categorization</b>	Each reported complaint is categorized by severity (e.g., low, medium, or high), and the distribution of complaints across these severity levels is modeled.
<b>Resolution Time</b>	The average time taken to resolve complaints is assessed for each severity level, providing a baseline for comparison.

The simulation method utilizes historical complaint records categorized by severity and integrates Monte Carlo Simulation to simulate and iterate the data before and after CMMS implementation.

To execute the simulation and evaluate the effectiveness of CMMS, five key formulas were employed. Each formula is described in Table 3.6 below with full notation and explanation.

Table 3.6  
Overview of the Formula Equation Table

No	Equation
1	$\text{Avg Complaints } (\bar{x}) = \frac{\sum_{i=1}^n I_{Complaints_{Daily}}}{n} \quad (Z \text{ Complaints Daily}) \quad (3.2)$

Where:

- $(\bar{x})$ : Average number of complaints per day
- $I_{Complaints_{Daily}}$ : Number of complaints received on daily
- n: Total number of days in the simulation period (typically 31/30)

Purpose: To calculate the average daily complaint volume, providing a baseline for resource allocation and modeling future events.

$$\text{Standard Deviation } (\sigma) = \sqrt{\frac{\sum_{i=1}^n (X_j - \bar{x})^2}{n}} \quad (3.3)$$

Where:

- $(\sigma)$ : Standard deviation of complaints per day
- $X_j$ : Number of complaints on day iii
- $\bar{x}$ : Average complaints per day (from Formula 1)
- n: Number of days in the simulation

Purpose: To measure the variability in daily complaint occurrences, indicating the range of fluctuation in workload.

$$Td_{Initial} = Z(S_i \times D_i) \quad (3.4)$$

Where:

- $Td_{initial}$ : Total number of complaint resolution days before CMMS implementation
- $S_i$ : Number of complaints of severity level  $i$
- $D_i$ : Average number of days to resolve severity  $i$  complaints without CMMS

Purpose: To estimate the total resolution time using the current manual process for comparison.

$$Td_{CMMS} = \sum (S_i \times D_i) \quad (3.5)$$

Where:

- $Td_{CMMS}$ : Total complaint resolution time after CMMS implementation
- $D_i$ : Average number of days to resolve severity  $i$  complaints with CMMS
- Other terms as previously defined

Purpose: To simulate improved resolution times under an automated CMMS-enhanced workflow.

$$Improvement (\%) = \frac{(Td_{initial} - Td_{CMMS})}{Td_{Initial}} \times 100\% \quad (3.6)$$

Where:

- $Improvement (\%)$ : Percentage of time saved due to CMMS implementation

Purpose: To quantify the benefit of CMMS in terms of time efficiency.

The simulation was conducted using Microsoft Excel with random number generation to replicate historical distributions. Each day of the month was simulated based on:

- Whether a complaint occurred
- How many complaints occurred
- Severity level assignments
- Resolution duration using pre-defined average days

This process was repeated for 10 iterations per month. The total number of days required to solve all complaints under both pre-CMMS and post-CMMS workflows was calculated using Formulas 3 and 4 respectively. The percentage improvement was then computed using Formula 5. The final iteration table of each month will be recorder as per table below.

Table 3.7  
Final Monthly Iteration Table

Iteration	Pre-CMMS (Days)	Post-CMMS (Days)	Improvement (%)
1	120	100	16.67
2	115	95	17.39
3	110	90	18.18
4	105	85	19.05
5	100	80	20.00
6	95	75	21.05
7	90	70	22.22
8	85	65	23.53
9	80	60	25.00
10	75	55	26.67

10

**Improvement Percentage**  
(%)

In summary, this simulation approach using Monte Carlo methods provides a structured framework to evaluate the impact of CMMS on complaint resolution times. By simulating both pre- and post-CMMS scenarios, the model offers a quantitative

comparison of operational efficiency. The next chapter will discuss the results of these simulations, offering insights into the effectiveness of CMMS in improving maintenance response times and overall service delivery.

### 3.6 Evaluation by Public Work Department (PWD)

Collaborating with stakeholders as such the Public Work Department (PWD) of Selangor is to gather feedback and insights that will ensure the development of CMMS aligns with their requirements and operational needs of the organisation.

The Focus Group Discussion (FGD) was conducted to qualitatively validate the Monte Carlo simulation findings and to capture operational insights from practitioners within PWD Selangor. The session aimed to evaluate the feasibility, readiness, and organisational implications of integrating CMMS with the existing REACT system.

To ensure the successful development and adoption of the proposed Computerized Maintenance Management System (CMMS) model, it is imperative to engage with PWD representatives and gather their valuable insights, feedback, and recommendations. The focus group discussions serve as a structured platform for this purpose to gather more focus insights on the CMMS development.

During these sessions, selected representatives from PWD, including manager, head or project engineers, and technician, will come together to participate in a closed and constructive Focus Group Discussion (FGD) individually. The discussion will be made individually to prevent biased and influence from the other respondent. The primary objective of these discussions is to capture their collective expertise, experiences, and expectations related to the CMMS model and current unified systems. Table 3.8 shows the discussion topic to be focused on during the discussion.

Table 3.8  
Discussion Highlights during Interview

<b>Discussion Topic</b>	<b>Description</b>
<b>Feedback On Proposed CMMS Model</b>	Introduction to the proposed CMMS model and detailed feedback from participants.
<b>Output</b>	Participants express preferences, suggest modifications, and recommend additional features.
<b>Integration and Workflow</b>	Discussion on how the CMMS model integrates with existing PWD systems and workflows.
<b>Output</b>	Exploration of potential adjustments required for

seamless integration.

<b>Performance Indicators</b>	Identification of key performance indicators to monitor the effectiveness of asset management and maintenance.
<b>Obstacles And Mitigation</b>	Exploration of potential obstacles and concerns related to CMMS implementation.
<b>Strategies</b>	Encouragement for PWD representatives to propose strategies to mitigate concerns and ensure a smooth transition.

It is essential to establish clear response criteria for evaluating the feedback and input received from different stakeholders within the PWD organization. The response criteria will help in assessing the feasibility, relevance, and alignment of the proposed CMMS with the specific needs and goals of development of CMMS in a unified platform. The selection of respondent is explained in Table 3.9. These criteria ensured that perspectives were gathered from different operational levels, namely top management, middle management, and field level technicians reflecting strategic, operational, and technical viewpoints.

Table 3.9  
Focus Group Respondent Criteria

<b>Criteria/ Position</b>	<b>Head Engineer</b>	<b>Project Engineer</b>	<b>Technician</b>
<b>Level In the Organization</b>	Top Management: The Decision Maker, have rights on budgeting and planning	Middle Rank Management: Person who manage work on ground and monitor project	On Ground Management: Technician experts upon hands on and assets system
<b>Knowledge On REACT</b>	Good extent of knowledge and familiarity with the existing	Good understanding of the REACT system and how it currently supports	Can Share their knowledge level regarding the REACT system

	REACT system.	their projects.	and its functions.
<b>Knowledge On Electrical Assets</b>	Understand electrical assets within the context of their roles.	Have broader understanding on electrical asset management and can impacts their projects.	Have insights into their knowledge of electrical assets and their relevance
<b>Performance Indicators</b>	Budgeting and Planning	Project Planning and manage budget	Installation or Maintenance

The questionnaire is divided into three categories, each addressing a distinct aspect of the CMMS implementation: system integration, key performance indicators (KPIs), and identification of potential obstacles. Tabel 3.10 Below is a structured presentation of the questions categorized accordingly:

Table 3.10  
Proposed Questionnaire Design for CMMS Implementation

<b>Section</b>	<b>Question Number</b>	<b>Question</b>
<b>System Integration and Maintenance Data</b>	1	REACT is a monitoring platform that tracks road electrical assets; however, it currently lacks maintenance components. Do you think maintenance information and components should be incorporated into the REACT system? If so, please provide reasons for your opinion.
	2	The specific features or functionalities of the maintenance model must be most effective and customized for PWD. Do you agree with this statement?
<b>Key Performance Indicators (KPIs) for CMMS</b>	3	The following are the key performance indicators the CMMS should track to ensure effective asset management and maintenance: work order

management, asset management, maintenance management, inventory management, and reporting management. What do you think about these indicators?

- Identifying Obstacles and Mitigation Strategies**
- 4 How do you anticipate the CMMS model integrating with your existing systems and workflows, and what support or changes might be needed for the integration?
  - 5 Can you identify any potential obstacles or concerns regarding the implementation of the proposed CMMS model, and what strategies would you suggest to mitigate these concerns?
  - 6 What do you see as the biggest potential obstacles to successful CMMS implementation at PWD, and what strategies would you recommend to overcome these challenges?

The questionnaire is designed to encourage open and honest feedback from stakeholders, including head engineers, project engineers, and technicians within PWD. Their input will be crucial in shaping the development and customization of the CMMS to meet PWD's operational needs.

- Section 1 focuses on system integration and the incorporation of maintenance data within REACT. This section assesses whether stakeholders believe integrating maintenance information into REACT will improve asset management and operational efficiency.
- Section 2 addresses key performance indicators (KPIs) that should be tracked by the CMMS. This section aims to determine which KPIs are most important to PWD's daily operations and whether the proposed CMMS will meet these requirements.
- Section 3 explores potential obstacles to CMMS implementation. It identifies challenges that could hinder the system's adoption and gathers suggestions for mitigating these issues.

The proposed questionnaire plays a vital role in gathering the insights necessary to tailor the CMMS framework to PWD's specific needs. By dividing the questions into clear categories system integration, KPIs, and potential obstacles the questionnaire provides a structured approach to collect targeted feedback. The responses will be analysed and used to refine the CMMS model, ensuring that it aligns with PWD's operational workflows and enhances the management of road electrical assets.

In section A, the focus was on understanding the current REACT system used by the Public Works Department (PWD) of Selangor and its limitations. While REACT serves as a monitoring platform for road electrical assets such as traffic lights and street lighting, it lacks a dedicated maintenance component. The panel suggest how critical it is to integrate maintenance data directly inside REACT rather than maintaining it as a separate multiple system. The consensus was that integrating maintenance information such as asset status, repair needs, and lifespan into the REACT system would significantly improve the operational efficiency of the PWD. Currently, the system only provides real-time data, which is insufficient for proactive maintenance. This feature has led to delays in addressing malfunctions and other issues, making it harder to manage road assets proactively. Participants highlighted the need for a more integrated approach, which would enable better decision making and quicker response times.

In technical aspects or Section B, the question focused on the technical features of CMMS and how it could enhance PWD's daily operations. The panel discussed which of the five key CMMS components from work order management, asset management, maintenance management, inventory control, and reporting management would provide the most immediate value to PWD. It was emphasized that maintenance management can be prioritized, particularly for managing traffic lights and street lighting, which are critical components for smooth traffic flow and road safety. Additionally, the panel expressed the need for the CMMS to be customized to fit PWD's specific workflows. Suggestions included the integration of AI cameras for real-time monitoring, QR code tracking for asset management, and ensuring real-time updates for better tracking of asset conditions. Furthermore, it was highlighted that seamless integration between REACT and CMMS would be essential to ensure smooth data flow and avoiding operational silos, which would otherwise become ineffective management of assets.

The last section in Complaint Resolution Analysis examined how CMMS could optimize the current complaint management process. The panel were told regarding the reduction of 11% improvement in Complaint Response by eliminating certain hierarchical steps in the complaint resolution process. While this improvement might seem small, the panel agreed that even such a reduction would make a significant difference in the overall efficiency of the system. Slight improvement is better than no improvement. Additionally, participants discussed how having access to historical maintenance records would allow the team to diagnose and address complaints more quickly, as past data would provide insights into recurring issues. The ability to track and manage complaints in real-time, as well as streamline the process, was seen as essential for improving response times and reducing delays.

The FGD concluded with a discussion on the potential obstacles to successfully implementing CMMS within the PWD. Budget constraints were identified as a major challenge, as well as limitations in human resources and field delays. The panel recommended that CMMS be implemented in phases, with asset management and maintenance management being the priority. This would be followed by integrating asset management, inventory control, and reporting management. The phased approach would allow PWD to focus on the most critical aspects first, ensuring that the system is effective and feasible within budget constraints.

The panel members emphasized the importance of integrating maintenance data into the REACT system, prioritizing maintenance management, and adopting a phased implementation strategy to overcome budget and resource limitations. With these improvements, the PWD could achieve better efficiency, faster response times, and more effective management of its road electrical assets.

Thematic analysis was used to categorize, interpret, and present the qualitative data derived from these discussions. This approach allowed identifying recurring themes, examining their frequency, and drawing meaningful conclusions from the data to support the research objectives. The analysis also highlights how different roles and hierarchical positions within PWD perceive the need for a Computerized Maintenance Management System (CMMS) and how various operational challenges impact the feasibility of CMMS integration into the existing Road Electrical Asset Control & Telemetry (REACT) platform.

### **3.6.1 Data Analysis Method**

Responses from these discussions was recorded and analysed using the ATLAS.ti software. Qualitative analysis techniques will be applied to identify common themes, patterns, and critical insights. This analysis will be instrumental in shaping the CMMS model to align with the specific needs and priorities of PWD. The weightage of the discussion was set to three suitable outcomes which are positive, neutral, and negative for each question.

All responses were audio-recorded, transcribed, and analysed using ATLAS.ti 23. A thematic analysis approach was used, following the six-phase process of (i) familiarisation with transcripts, (ii) open coding, (iii) grouping codes into categories, (iv) developing themes, (v) reviewing themes, and (vi) reporting findings. Coding was done manually in ATLAS.ti, and both frequency and interpretive significance were considered when forming themes.

Each question was analysed for three possible outcome perspectives: positive, neutral, and negative. This categorisation allowed the study to systematically identify areas of strong support, uncertainty, and resistance towards CMMS implementation. The feedback and recommendations gathered from the focus group discussions will play a pivotal role in developing a CMMS model that is not only technically robust but also closely aligned with the real-world requirements and operational workflows of the PWD. This collaborative approach ensures that the resulting CMMS model has a high likelihood of successful implementation and acceptance within the organization Focus Group Discussion to Propose to Public Work Department (PWD).

### **3.7 Chapter Summary**

In summary, this chapter outlined the structured methodology employed to achieve the research objectives. The process began with a document and system review, which successfully identified a key area for improvement to enhance system feasibility before having the CMMS. Building on this, a simulation system needs to be tested with the implementation of CMMS, enabling the visualization or improvements using simulation software Anylogic. Finally, insights and validation will be obtained through

a focus group discussion (FGD), where stakeholders or the organisation provided critical feedback on the proposed solutions. The combination of these methods ensured a comprehensive and systematic approach of the research, laying a guide for the research findings and recommendations in subsequent chapters.

## CHAPTER 4

### RESULTS AND DISCUSSIONS

#### **4.1 Introduction**

In this chapter, the findings from the research will be presented and analysed. The expected result of the study is to see the feasibility of integrating CMMS into the unified system in monitoring road electrical assets such as traffics lights and street lighting. The chapter examine the existing application practice and measure time effectiveness from the initial practice comparing it to the new proposed system, which then be presented to the PWD organisation.

#### **4.2 Examining the Characteristics of Unified System (Current System)**

The depth of implementing a proper CMMS can be identified by referring to the data category existed within the system. Even with existing real time monitoring features, a system may not be ready for implementing Computerised Maintenance Management System. Table 4.1 helps to determine the readiness of the system to adopt a CMMS function. The table was verified by the system owner and system integrator which explains the data elements through each data category that is implemented or practiced in the REACT system. This also allow us to see the overall readiness of the system to implement CMMS.

Table 4.1 also compares the readiness of the CMMS from the system integrator or system provider and the elements implemented at organization level. From 10 types of data category focus for CMMS and 22 data elements which was reviewed from both parties, system integrator gave 9 out of 22 data elements or 41% leaning towards 'yes' while implementation at organizational level only gave a 7 out of 22 which are 32% leaning towards 'yes'. At average, both levels resulted a 36.5% leaning towards 'yes' which means CMMS are only ready in REACT system at average 35.6%.

Table 4.1  
Data Elements of REACT and Maintenance Information

<b>Data Category</b>	<b>Data Elements</b>	<b>Importance for Maintenance</b>	<b>Implemented / Practiced (System Integrator)</b>	<b>Implemented / Practiced (System Owner)</b>
<b>Asset Identification</b>	Asset name or description	Helps in quick asset identification during maintenance.	Yes	Yes
	Unique asset identifier or serial number	Ensures precise tracking of individual assets.	Yes	Yes
	Asset location (geographical or within a facility)	Enables maintenance teams to locate assets efficiently.	Yes	Yes
	Asset category or type (e.g., equipment, machinery, vehicles)	Aids in organizing maintenance tasks by asset type.	Yes	Yes
<b>Asset Specifications</b>	Technical specifications and details	Provides insights into asset capabilities and requirements.	Yes	Yes
	Manufacturer information	Helps in sourcing parts and expertise for repairs.	Yes	No
	Installation date	Determines the asset's age and potential maintenance needs.	Yes	Yes
	Expected service life	Indicates when major overhauls or replacements may be required.	No	No
<b>Maintenance History</b>	Records of past maintenance and repairs	Offers insights into recurring issues and preventive measures.	No	No
	Maintenance schedules and plans	Guides future maintenance and inspections.	No	No
<b>Warranty and Documentation</b>	Warranty information	Ensures compliance with warranty terms and conditions.	No	No
	Manuals and documentation related to the asset	Assists in proper maintenance and troubleshooting.	No	No

<b>Asset Condition</b>	Current condition or status of the asset (New or Spare)	Provides a snapshot of immediate maintenance requirements.	Yes	Yes
	Inspection reports	Records observations for potential corrective actions.	No	No
<b>Asset Criticality</b>	Importance or criticality of the Asset to operations (minimum lifespan estimation)	Guides prioritization of maintenance efforts.	No	No
<b>Spare Parts and Inventory</b>	List of spare parts and associated inventory	Facilitates quick part replacement during maintenance.	No	No
	Ordering and restocking details	Maintains efficient inventory management for minimal downtime.	No	No
<b>Maintenance Tasks</b>	List of routine maintenance tasks required	Forms the basis for maintenance planning and schedules.	No	No
	Frequency and procedures for maintenance	Guides technicians in performing maintenance tasks correctly.	No	No
<b>Maintenance Contacts</b>	Personnel responsible for asset maintenance	Ensures accountability and easy contact for maintenance teams.	Yes	No
	Contact information for maintenance providers	Facilitates external service provider coordination.	No	No
<b>Failure and Incident Reports</b>	Records of asset failures, breakdowns, or incidents	Offers insights into asset weaknesses and areas for improvement.	No	No

Based on the table, many major data categories are not ready or prepared to be used in the system which will make CMMS far more difficult to implement. As such basic records for maintenance are not available directly through the system and failure records are separated from the online system. Moreover, data cannot be accessed by all

maintenance personnel and assets information are separated to different rights and not accessible through the system.

Other parts to highlight in the existing system review is the complaints or incident reports received from road users are not recorded in the system. As failure reports can offer insights into assets weakness and areas of concern and improvement. A proper CMMS functions with complaint failure reports may help identify asset weaknesses and improve maintenance functions.

### 4.3 Maintenance Documents

By consolidating the documentation used during initial registration and ongoing maintenance, the significance of maintaining this information within a Computerized Maintenance Management System (CMMS) becomes clearer. Documentations relating to asset management either initial installation or planning and maintenance used by the organisation was given by PWD officers in charge of electrical asset management and maintenance for study.

Table 4.2 listed all the documents name and its description explaining the purpose of the documents, some information may be used throughout the whole asset management maintenance process. Then, the list of documents is categorised for each data category of CMMS it is suitable with. The study assigns the data category for CMMS for each document used in the electrical asset maintenance management.

Table 4.2  
Types of Documentation Used for Electrical Registration and Maintenance

Num	Document Name	Document Description (Digunakan untuk apa)	Data Category
1.	<b>Matching Grant Agreement (APJ Geran Padanan)</b>	A formal contract table outlining the information for matching maintenance funding. This ensures maintenance work aligned in financial and project expectations.	Asset Identification Asset Specification Asset Condition Asset Criticality Spare Parts & Inventory Maintenance Tasks Failure & Incident Reports
2.	<b>Street Lighting Inventory Form (Inventori Lampu Jalan)</b>	An overall detail of street lighting infrastructure, including location, specifications, and operational status. It helps maintain an organized	Asset Identification Asset Specification Asset Condition Asset Criticality

		overview of street light installations.	Spare Parts & Inventory
3.	<b>Traffic Light Inventory Form (Inventori Lampu Isyarat)</b>	An overall detail of traffic light infrastructure, including location, specifications, and operational status. It helps maintain an organized overview of traffic light installations.	Asset Identification Asset Specification Asset Condition Asset Criticality Spare Parts & Inventory
4.	<b>Factory Acceptance Test (Checklist for Visual Inspection of Low Voltage Electrical Boards)</b>	A comprehensive checklist used during the Factory Acceptance Test (FAT) process to visually inspect low-voltage electrical boards. It ensures that equipment meets all technical requirements before delivery to the site.	Asset Identification Asset Specification Asset Condition Asset Criticality Spare Parts & Inventory Warranty and Documentation
5.	<b>MySPATA D.A.(E)</b>	Streamline maintenance system and asset tracking processes. Contains 9 different form from D.A.(E) 1-9.	Asset Identification Asset Specification
6.	<b>Complain Form Appendix Form 1- Form 5 (Borang Aduan Lampiran 1-5)</b>	These forms provide a structured way to handle and resolve issues effectively. Contains a complaint form, a complaint registration format form, a format for investigation instructions and corrective actions, a complaint summary format, and a customer satisfaction survey form	Asset Condition Asset Criticality Spare Parts & Inventory Failure & Incident Reports Maintenance Contacts Maintenance Tasks Maintenance History
7.	<b>Warranty Declaration Form</b>	A formal document outlining the terms and conditions of a product or system's warranty. It specifies the duration of the warranty and the coverage for repairs or replacements, giving confidence to the end-users about the product's reliability.	Asset Identification Asset Specification Warranty Documentation
8.	<b>Traffic Light (Factory Acceptance Test Form)</b>	This ensures that the traffic light feeder pillars are properly functioning and meet electrical safety standards.	Asset Identification Asset Specification Asset Condition Asset Criticality Warranty Documentation
9.	<b>Street Lighting Feeder Pillar (Factory Acceptance Test Form)</b>	This form ensures that the feeder pillars are properly functioning and meet electrical safety standards	Asset Identification Asset Specification Asset Condition Asset Criticality Warranty Documentation
10.	<b>Monthly Report on Damage Complaints and Electrical Services (Laporan bagi Aduan Kerosakan dan Perkhidmatan Elektrik)</b>	A monthly report that summarizes complaints regarding electrical damage and services provided. It helps in tracking recurring issues and improving service quality over time.	Asset Condition Asset Criticality Spare Parts & Inventory Failure & Incident Reports Maintenance Contacts Maintenance Tasks Maintenance History

11.	<b>On-Site Asset Damage Report. (Laporan Kerosakan Aset di Tapak)</b>	A report detailing damage to assets that occurred on-site. This report helps in understanding the nature of the damage and determining necessary repairs or replacements.	Asset Criticality Asset Condition Maintenance Tasks Maintenance Contacts Failure and Incident Report Maintenance History Spare Parts & Inventory
12.	<b>Maintenance Work Report (Laporan Kerja Senggaraan)</b>	A formal report outlining the maintenance activities performed on equipment or infrastructure. It tracks the tasks completed, the duration of work, and the status of the equipment after maintenance.	Asset Criticality Asset Condition Maintenance Tasks Maintenance Contacts Maintenance History Spare Parts & Inventory
13.	<b>Spare Parts Inventory List (Inventori Barangan Elektrik)</b>	A detailed record of all electrical spare parts available in inventory. This list typically includes information such as part names, descriptions, quantities, storage locations, and reorder levels.	Spare Parts & Inventory Asset Criticality Asset Condition Maintenance Tasks Maintenance Contacts Maintenance History

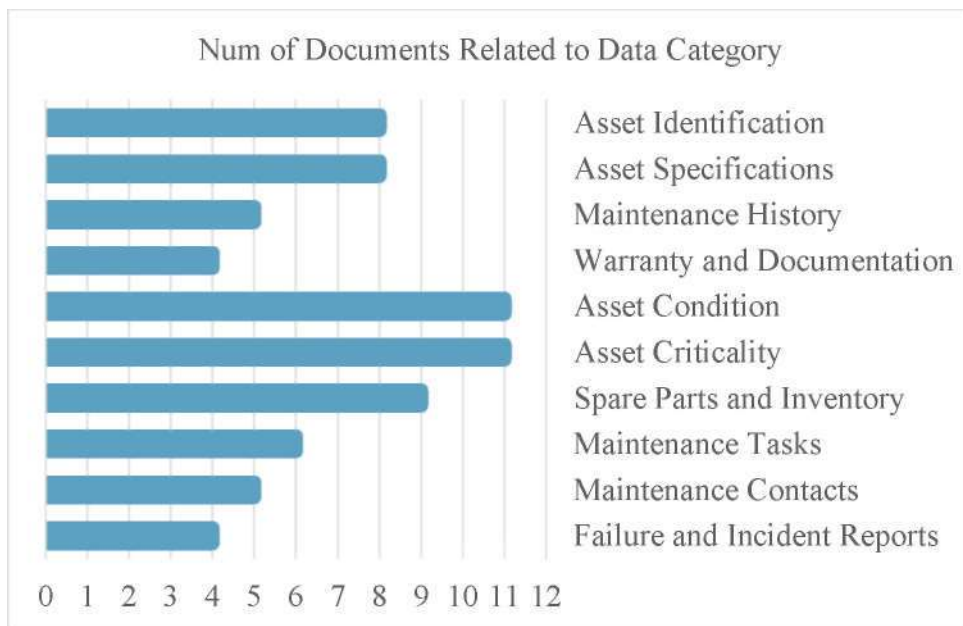


Figure 4.1 Number of Documents Related to Data Category

From Figure 4.1, it is evident that the Asset Condition and Asset Criticality categories dominate the dataset, with 12 out of 13 documents falling under these categories. This highlights their significance as the most frequently documented areas, reflecting their critical role in the overall analysis. Whilst the lowest number of 4 documents related to the data category are Warranty Documentation and Failure Incident Reports.

However, from the identification of CMMS data category, the research considers the lowest number of documents related to its data category which are Failure and Incident Reports to be studied. Warranty Documentation in the other hand was not selected as it is recorded on the initial phase of planning and maintenance. The reason towards this selection is also because the data gathered through complaints is already immense.

#### Failure Records 2023

In year 2023, the total number of complaints records for state of Selangor recorded by only PWD of Selangor reached up to the number of 5924 complaints in a year. In Petaling district alone, complaints gathered up to 1723 which is 30% out of the total complaint records distributed towards 9 districts in Selangor. Table 4.3 shows the complaint reports collected from PWD of Selangor.

Table 4.3  
Complaint Records from PWD of Selangor for the year 2023.

<b>NUM</b>	<b>MONTH</b>	<b>NUMBER OF COMPLAINTS RECORDED (DISTRICT: PETALING)</b>
<b>1</b>	JANUARY	153
<b>2</b>	FEBRUARY	135
<b>3</b>	MARCH	159
<b>4</b>	APRIL	86
<b>5</b>	MAY	127
<b>6</b>	JUNE	85
<b>7</b>	JULY	100
<b>8</b>	AUGUST	152
<b>9</b>	SEPTEMBER	167
<b>10</b>	OCTOBER	165
<b>11</b>	NOVEMBER	210
<b>12</b>	DECEMBER	184
<b>Total Number of Complaints</b>		<b>1723</b>

From the total number of complaints in Petaling district, 39 percent of the complaints registered falls under the Electrical Component Related for road complaints with 670 complaints within the year 2023. Table 4.4 shows the distribution of complaints for electrical component within each month.

Table 4.4  
Complaint Records from PWD of Petaling District for the year 2023.

<b>Num</b>	<b>Month</b>	<b>Number Of Complaints Recorded (District: Petaling)</b>	<b>Number Of Complaints Electrical Component Related</b>
<b>1</b>	JANUARY	153	56
<b>2</b>	FEBRUARY	135	69
<b>3</b>	MARCH	159	68
<b>4</b>	APRIL	86	33
<b>5</b>	MAY	127	49
<b>6</b>	JUNE	85	25
<b>7</b>	JULY	100	42
<b>8</b>	AUGUST	152	71
<b>9</b>	SEPTEMBER	167	67
<b>10</b>	OCTOBER	165	68
<b>11</b>	NOVEMBER	210	67
<b>12</b>	DECEMBER	184	55
<b>Total Number of Complaints</b>		1723	670
<b>Electrical Weightage of Total Number of Complaints</b>			39%

The study goes deeper to the number of days of a complaint registered to be informed or solved to road user. It's important to know the number of days solved because the effectiveness of asset failure registration reflects the rapidity of maintenance actions and swiftness in maintenance records. Table 4.5 shows in detail the data collected for the duration of complaint solved for the whole year 2023 in Petaling District.

Table 4.5  
Time Response for Complaint to Solved from PWD of Petaling District year 2023.

NUM	MONTH	NUMBER OF COMPLAINTS ELECTRICAL COMPONENT RELATED	DAYS COMPLAINTS REPLIED TO CUSTOMER (SOLVED)								
			Q A	Q A	in Q A	m Q A	m Q A	m Q A	m Q A	m Q A	
1	JANUARY	56	6	23	9	6	6	6	0	0	0
2	FEBRUARY	69	3	23	25	12	4	2	0	0	0
3	MARCH	68	6	23	18	12	5	4	0	0	0
4	APRIL	33	3	12	6	4	3	5	0	0	0
5	MAY	49	6	31	9	1	0	2	0	0	0
6	JUNE	25	3	8	4	5	0	5	0	0	0
7	JULY	42	2	5	8	2	3	22	0	0	0
8	AUGUST	71	5	23	18	7	9	9	0	0	0
9	SEPTEMBER	67	5	29	6	4	4	19	0	0	0
10	OCTOBER	68	6	16	19	5	0	22	0	0	0
11	NOVEMBER	67	9	4	7	0	0	35	10	2	0
12	DECEMBER	55	4	11	1	1	0	32	4	2	0
<b>Total Number of Complaints</b>		670									
<b>Total Occurrence Days Complaints Replied to Customer</b>			00	00	0	08					0

The duration of days solved was separated into nine different period starts from zero days or same day, one day to a week, then move weekly until monthly and up to 4 months. As the data above show no complaints exceeded the 120 days mark. Most complaints records were replied to customer or road user within 3 months period, and the reason may be because different issues or complaints may have different severity actions.

Before focusing on a month-long simulation, data from the past year was collected to determine the average time taken to resolve a complaint. As shown in Table 1, the average resolution time is 23 days, which exceeds the PWD Customer Charter's target of 14 days for complex complaints by 9 days. The data indicates that most complaint tickets are not resolved within 7 or 14 days.

Table 4.6  
The Average Number Of Days For Complaint To Solve

Distribution of Days	Mid Values	Frequency Complaint	Total number of Days
0 TO 1	0.5	58	29.0
2 TO 6	4	208	832.0
7 TO 13	10	130	1300.0
14 TO 20	17	59	1003.0
21 TO 27	24	34	816.0
28 TO 59	57.5	163	9372.5
60 TO 90	75	14	1050.0
90 TO 120	105	4	420.0
<b>Total</b>		670	14822.5
<b>Average Number of Days</b>			22.1
<b>Average Days for a Complaint to be Solved</b>			<b>23</b>

While most complaints are resolved within 2 to 6 days, a significant portion of complaints (163 cases) takes between 28 to 59 days to resolve, contributing to a total of 9,372.5 days. The overall average resolution time is 23 days, which exceeds the PWD Customer Charter's target of 14 days for complex complaints by 9 days. The data highlights that a considerable number of complaints, especially those taking over 28 days, significantly impact the overall resolution time. This indicates inefficiencies in the complaint resolution process, suggesting that attention should be given to addressing the delays, particularly in the longer resolution time ranges, to improve customer satisfaction and align more closely with the targeted resolution times.

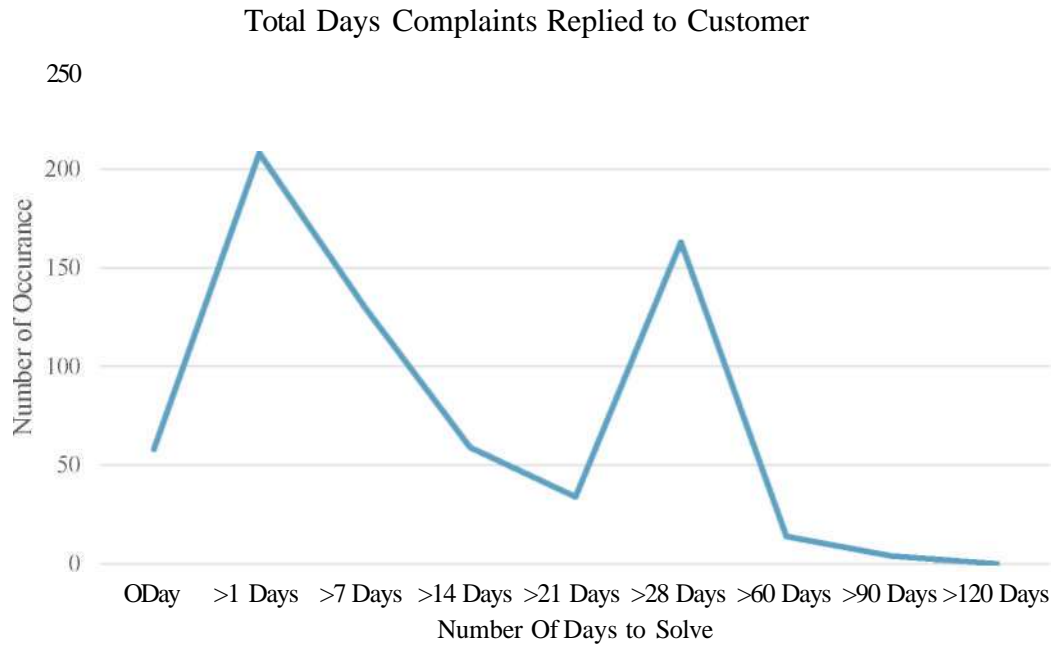


Figure 4.2 Total Days Complaint Replied to Customer

Figure 4.2 shows the variation distribution of the total number of days needed for a complaint to be solved. The highest number of complaints solved is within 1 day to a week and between 28 to 60 days. In failure breakdown or incident reports in CMMS, the duration between initial breakdown and corrective actions is important, which provides an area for improvement for maintenance activities.

According to the Customer Charter of JKR Malaysia, the completion time for electrical asset maintenance works is set based on the complexity of the damage. Minor damages are expected to be resolved within 1 day, while complex issues should be addressed within 7 days. These timelines reflect the commitment to prompt and efficient service delivery. From the data, only 39% of complaints were resolved within 7 days, and 61% are above the standard charter completion time.

From the data collected, many complaints were successfully resolved or replied within the stipulated 7-day period, aligning with the charter's guidelines. However, there is still a large number of complaints that require more than 28 days for resolution or response. This delay may be attributed to factors such as the complexity of the work

involved or limitations in budget allocation, both of which can hinder the efficiency of the maintenance process.

Establishing the long period of days for a complaint to be solved, the process of complaint records needs to be considered in the action taken. Hence referring to table 4.2, Complaint Form which have 5 different manual forms to be filled and may require different person in charge of action which may add additional time taken for a complaint to be solved.

#### 4.4 The Monte Carlo Simulation

The focus of the simulation is on optimizing the resolution of electrical complaints, specifically those related to traffic lights and street lighting in the Selangor district. The simulation compares the performance of the current system (without CMMS) to the proposed CMMS-enhanced system, using complaint resolution time as the key performance indicator. The goal is to quantify how CMMS implementation can improve the efficiency and speed of resolving complaints by streamlining workflows and seeing this through complaint management.

The Monte Carlo simulation was chosen for this study due to its ability to model uncertainty and variability in complex systems. In the context of the complaint resolution process, several factors contribute to uncertainty, including:

- Complaint occurrence: The likelihood of complaints being reported or to happen on a given day.
- Number of complaints per day: The daily volume of complaints that need to be addressed.
- Severity of complaints: The level of urgency or complexity associated with each complaint, which directly impacts the resolution time.

The complaint occurrences in each month during the simulation may vary, with the total number of complaints per day differing based on the probability distribution. The probability of recurring complaints and the cumulative probability were calculated so that, during each iteration, a random number generated would correspond to the specific occurrence of complaints on that day. Table 4.7 is the spread for occurrence and its probabilities.

Table 4.7  
Complaints Occurance for the Month of January (Sample)

<b>Date: January</b>	<b>Number of Complaints Occurrence</b>	<b>Probability</b>	<b>Cumulative Probability</b>	<b>Random Number (2 Digit)</b>
<b>1</b>	<b>0</b>	<b>0%</b>	<b>0%</b>	00-00
<b>2</b>	<b>0</b>	<b>0%</b>	<b>0%</b>	00-00
<b>3</b>	<b>2</b>	<b>4%</b>	<b>4%</b>	01-04
<b>4</b>	<b>3</b>	<b>5%</b>	<b>9%</b>	05-09

<b>5</b>	1	2%	11%	10-11
<b>6</b>	1	2%	13%	12-13
<b>7</b>	0	0%	13%	14-15
<b>8</b>	0	0%	13%	16-17
<b>9</b>	3	5%	18%	18-19
<b>10</b>	4	7%	25%	20-25
<b>11</b>	6	11%	36%	26-36
<b>12</b>	2	4%	39%	37-39
<b>13</b>	2	4%	43%	40-43
<b>14</b>	0	0%	43%	44-45
<b>15</b>	0	0%	43%	46-47
<b>16</b>	3	5%	48%	48-49
<b>17</b>	4	7%	55%	50-55
<b>18</b>	1	2%	57%	56-57
<b>19</b>	1	2%	59%	58-59
<b>20</b>	2	4%	63%	60-63
<b>21</b>	0	0%	63%	64-65
<b>22</b>	0	0%	63%	66-67
<b>23</b>	0	0%	63%	68-69
<b>24</b>	0	0%	63%	70-71
<b>25</b>	0	0%	63%	72-73
<b>26</b>	7	13%	75%	74-75
<b>27</b>	0	0%	75%	76-77
<b>28</b>	3	5%	80%	78-80
<b>29</b>	0	0%	80%	81-82
<b>30</b>	8	14%	95%	83-95
<b>31</b>	3	5%	100%	96-99
<b>Sum</b>	<b>56</b>			

The table above illustrates the distribution of complaint occurrences for the month of January, detailing the number of complaints per day, their associated probabilities, cumulative probabilities, and corresponding random number ranges for simulation. By using this data, a random number is generated during each iteration to determine the number of complaints on any given day, based on the cumulative probability.

This approach ensures that the occurrence of complaints follows the predefined probability distribution, with certain days having higher likelihoods of complaint occurrences, such as the 30th of January, which has the highest number of complaints

at 8, and others like the 7th, 8th, and 14th where no complaints were reported. This method allows for a realistic simulation of complaint occurrences, accounting for varying complaint frequencies throughout the month.

For number of complaints per day, each month will have different occurrence number in a day. During simulation, the occurrence of complaint changes based on the daily occurrence referred for that month to imitate the exact month sequence. Some days may have more, and some days may have less complaint or even zero complaints. Table 4.8 shows the complaint recurring for the month of January.

Table 4.8  
Number of Complaints Daily for Month of January (Sample)

Number of Recurring Complaints in a Day (January)	Probability Recurring	Cumulative Probability	Random Number
0	41.94%	42%	00-42
1	12.90%	55%	43-55
2	12.90%	68%	56-68
3	16.13%	84%	69-84
4	6.45%	90%	85-90
6	3.23%	94%	91-94
7	3.23%	97%	95-97
8	3.23%	100%	98-99

During the simulation, each day's complaint occurrence is determined based on these probabilities, ensuring that the sequence of complaints for the month follows the pattern reflected in the table. Some days may experience higher or lower complaint counts, with certain days having no complaints at all, while others might have multiple complaints. For example, 41.94% of the time, there will be zero complaints, and 16.13% of the time, there will be three complaints. This approach simulates realistic complaint flows, ensuring variability in the occurrence of complaints throughout each month.

The severity factor is a crucial element in this study, as different severity levels correspond to varying resolution times. The probability distributions for severity levels can become imbalanced due to the limited number of severity categories, with the "moderate" severity level having the highest probability of 56% throughout the year.

However, the accuracy of the simulation can be improved by adjusting the severity levels for each month. Table 4.9 shows the severity level distribution for the entire year, while Table 4.10 illustrates the severity spread for the month of January. Despite "moderate" being the most common severity level on a yearly basis, the "major" severity level has the highest occurrence in January. By using monthly severity data based on the 2023 complaint records, the precision of the simulation can be significantly enhanced.

Table 4.9  
Yearly Level of Severity Spread

<b>Severity Level</b>	<b>Rating</b>	<b>Frequency</b>	<b>Probability</b>	<b>Cumulative</b>	<b>Random Number</b>
Insignificant	1	54	8%	8%	00-08
Minor	2	56	8%	16%	09-16
Moderate	3	377	56%	73%	17-73
Major	4	134	20%	93%	74-93
Critical	5	49	7%	100%	94-100
Total		670	100%	100%	

Table 4.10  
Monthly Level of Severity Spread January (Sample)

<b>Severity Level</b>	<b>Rating</b>	<b>Month January</b>	<b>Probability</b>	<b>Cumulative</b>	<b>Random Number</b>
Insignificant	1	7	13%	13%	00-13
Minor	2	2	4%	16%	14-16
Moderate	3	17	30%	46%	17-46
Major	4	21	38%	84%	47-84
Critical	5	9	16%	100%	85-00
Total		56	100%	100%	

This refined approach allows the simulation to better mimic real-world variations in severity levels, as complaint severity can fluctuate month to month. For instance, while moderate severity complaints may dominate overall, certain months like January might experience a higher frequency of major or critical complaints, affecting

the resolution timelines. By considering these variations, the simulation's accuracy is improved, providing a more realistic representation of how complaints are handled throughout the year and allowing for more accurate simulation.

## 4.5 Analysis on the Simulation Results

The simulation conducted in this study aimed to assess the impact of implementing a Computerized Maintenance Management System (CMMS) on the efficiency of complaint resolution within the Public Works Department (PWD) of Selangor.

In Table 4.11, a comprehensive monthly breakdown of electrical complaints received throughout 2023, specifically focusing on the average number of complaints per day, the standard deviation, and the severity distribution across five levels. This tabulation was essential in structuring the simulation inputs used in the Monte Carlo analysis, particularly the random generation of complaint occurrences and severity levels.

Table 4.11  
Summary of Complaint Data for the Year 2023

<b>Month</b>							
<b>January</b>	1.45	1.93	6	2	14	19	0
<b>February</b>	1.68	2.31	1	1.7	32.3	13.4	2.8
<b>March</b>	1.56	2.08	4.5	2.3	25.4	8.2	7.9
<b>April</b>	0.53	1.28	1.2	2	6.3	5.4	0.9
<b>May</b>	0.82	1.64	2.2	4.7	12.2	8	0.7
<b>June</b>	0.29	0.70	1.2	2	4.7	1.5	0.4
<b>July</b>	0.63	1.16	1.1	2.7	12.2	3.1	0.4
<b>August</b>	1.57	2.11	2.5	2.7	33.1	7.8	3.5
<b>September</b>	1.19	1.80	4.4	2.3	24	6.1	0
<b>October</b>	1.51	1.86	4.7	5.2	23.3	12	3.8
<b>November</b>	1.26	1.82	2.4	3.9	28.4	3.8	0.4
<b>December</b>	0.98	1.80	5.5	2.7	20.4	3.2	1
<b>Average</b>	1.12	1.71	3.07	2.83	19.65	7.64	1.82

The overall average number of complaints per day across all months was 1.12, while the average standard deviation stood at 1.71. These figures suggest a moderate but variable complaint load, with some months such as February (1.68) and August (1.57) exhibiting higher-than-average complaint frequencies and fluctuations. Notably, the standard deviation for those months exceeded 2.0, indicating greater variability and unpredictability in daily complaints, which complicates resource allocation and workforce planning—a challenge that CMMS aims to address, as highlighted in the simulation model.

In terms of severity distribution, the dominant complaint type was Severity Level 3 (Moderate), averaging 19.65 complaints per month, followed by Severity Level 4 (Major) at 7.64. This aligns with the severity spread established during simulation variable setup where Severity Level 3 accounted for 56% of total complaints, confirming that moderate-level issues consistently form the bulk of maintenance demands.

Importantly, Severity Level 1 (Insignificant) and Level 5 (Critical) were the least reported, averaging 3.07 and 1.82 complaints per month, respectively. However, even though critical complaints (Level 5) are less frequent, their extended resolution times and potential risk to public safety emphasize the need for prioritization mechanisms, which are better facilitated through CMMS work order automation and severity tagging.

The month of June showed the lowest complaint frequency (0.29/day) and lowest severity count across all levels, reflecting either a seasonal dip or an operational improvement in earlier preventive maintenance. In contrast, February, March, and August displayed both higher frequencies and a higher spread across multiple severity levels, particularly major and critical, further reinforcing the significance of seasonal planning and workload forecasting within CMMS frameworks.

Collectively, this table validates the input reliability of the simulation model and offers empirical evidence supporting the need for systematic complaint tracking, prioritization, and automated scheduling as embedded in the proposed CMMS integration. It complements the findings in Table 4.7 where post-CMMS

implementation yielded a consistent 11% reduction in resolution time, especially in months with high complaint volume and variability.

Table 4.12 provides insight into monthly complaint patterns, supporting the simulation assumptions derived from Table 4.11. With an annual total of 670 complaints and a daily average of 1.84, the data confirms the variability shown earlier, particularly in months like February, August, and September, which recorded higher daily averages and maximum complaints per day (up to 9 complaints). These peaks coincide with higher severity counts and standard deviations in Table 4.11, reinforcing the challenges of managing fluctuating workloads.

Moreover, 135 days with zero complaints show that complaints are irregular, justifying the need for a stochastic approach like Monte Carlo simulation. The CMMS system addresses these fluctuations by automating complaint tracking and prioritization, ultimately contributing to the reduction in resolution time observed across the year.

Table 4.12  
Distribution of Complaints per Month (2023)

<b>Month</b>	<b>Total Failures</b>	<b>Daily Average</b>	<b>Maximum In a Day</b>	<b>Days With Zero Failure</b>
January	56	1.81	8	13
February	69	2.46	8	7
March	68	2.19	9	9
April	33	1.10	5	18
May	49	1.58	9	13
June	25	0.83	4	17
July	42	1.35	5	14
August	71	2.29	8	8
September	67	2.23	9	10
October	68	2.19	6	8
November	67	2.23	9	9
December	55	1.77	6	9
<b>Total</b>	<b>670</b>	<b>1.84</b>	<b>9</b>	<b>135</b>

The simulation was also designed to compare the pre-CMMS and post-CMMS scenarios by modelling key factors affecting the complaint management process. These factors include the probability of daily complaints, the number of complaints per day, and the severity levels of complaints. Using historical complaint data from 2023, the simulation incorporated Monte Carlo methods was iterated 10 times each month and compiled to each severity factor for the whole year. This can be seen in the simulation table are as shown in Table 4.13.

Even though only one process was removed from the complaint handling procedure, the results demonstrate a noticeable improvement in the average time taken to resolve complaints. The final resolution table are shown below in Table 4.13.

Table 4.13  
Improvement Percentage Yearly

<b>Month</b>	<b>Average Number of Complaint per Day</b>	<b>Monthly Standard Deviation</b>	<b>Average of Days Complaint to Solve Before CMMS</b>	<b>Average of Days Complaint to Solve with CMMS</b>	<b>Improvement Percentage (%)</b>
January	1.45	1.93	21.00	18.30	13%
February	1.68	2.31	24.00	21.50	10%
March	1.56	2.08	22.90	20.60	10%
April	0.53	1.28	22.10	19.40	12%
May	0.82	1.64	22.20	19.80	11%
June	0.29	0.70	22.00	19.60	11%
July	0.63	1.16	23.90	21.40	10%
August	1.57	2.11	24.10	21.60	10%
September	1.19	1.80	23.20	20.80	10%
October	1.51	1.86	22.50	19.90	12%
November	1.26	1.82	24.30	22.00	9%
December	0.98	1.80	22.80	20.50	10%
Average	1.12	1.71	22.92	20.45	11%

#### Pre-CMMS Scenario

Prior to CMMS implementation, the complaint resolution process was largely manual, involving several hierarchical approval layers and inefficient communication between departments. The simulation revealed that the average resolution time for

complaints in 2023 was 22.92 days. This extended period can be attributed to multiple inefficiencies, such as:

- Hierarchical delays: The approval process required multiple departments to review and act on complaints, resulting in significant delays.
- Inefficient prioritization: Without an automated system, complaints were often resolved in a less-than-optimal order, with high-severity issues not always prioritized adequately.
- Manual processing: Much of the complaint management was handled manually, increasing the potential for errors and delays.

Additionally, the standard deviation of 1.71 days in resolution time indicated substantial variability in the time taken to resolve complaints, suggesting that the process was unpredictable and highly dependent on individual circumstances. The extended resolution time and the unpredictability, particularly for critical and major complaints, were significant contributors to inefficiency in the current system.

#### Post-CMMS Scenario

Following the integration of CMMS, a marked improvement in the complaint resolution process was observed. The average resolution time decreased to 20.45 days, representing an 11% improvement over the pre-CMMS scenario. This reduction can be attributed to several key benefits facilitated by CMMS, such as:

- Streamlined workflows: CMMS automated many aspects of the complaint management process, such as task assignment and tracking, which significantly reduced delays and the need for manual intervention.
- Real-time updates: The system allowed for real-time tracking of complaints, ensuring that maintenance teams could act swiftly and efficiently.
- Improved prioritization: With CMMS, complaints were categorized and prioritized based on severity, allowing critical issues to be addressed promptly and preventing delays in high-priority maintenance.

The standard deviation in resolution times now decreased to 1.5 days, indicating that the process had become more consistent and predictable. This improvement in consistency highlights CMMS's ability to standardize the complaint management

process, thereby reducing uncertainty and ensuring that complaints are resolved in a timely and organized manner.

The simulation results showed a clear reduction in complaint resolution time, mainly due to the faster handling of complaints facilitated by CMMS. This system streamlined the process by reducing delays in passing complaints through different stages, enabling quicker resolutions. Predictive maintenance, a key feature of CMMS, allowed maintenance teams to address potential issues before they escalated, especially for high-priority assets like traffic lights and street lighting, reducing the need for emergency repairs and service disruptions.

While the data shows an 11% improvement, it is important to gather feedback from the Focus Group Discussion (FGD) to identify additional parameters that could further improve resolution times.

In summary, the simulation clearly demonstrates that CMMS can significantly enhance the efficiency, predictability, and consistency of the complaint resolution process within the Public Works Department (PWD). The 11% reduction in resolution time, along with better prioritization of high-severity issues and reduced variability in response times, shows CMMS's potential to optimize maintenance workflows and improve service delivery.

Moreover, CMMS helps ensure public safety by proactively managing critical infrastructure. This study highlights the value of adopting modern technological solutions like CMMS for better infrastructure management and asset maintenance in the public sector.

While the results are encouraging, further studies and real testing are needed to validate these findings over time and across a wider range of assets. Nevertheless, CMMS represents a promising solution for improving maintenance practices, optimizing resources, and enhancing service quality in road electrical asset management.

#### 4.6 Focus Group Discussion (FGD from PWD Selangor)

This section is a continuation, and a combination of the study explained in previous analysis. Focus group discussion with the Public Works Department (PWD) of Selangor which was a representation of a detailed thematic analysis.

The FGD session took place on 15 May 2025, from 2:00 PM to 5:00 PM, at Bilik Mesyuarat Ar Rahman, MITRANS, UiTM. The discussion was divided into three main segments: Unified Systems Overview, Technical Aspects of CMMS, Complaint Resolution Analysis.

The main objectives of the FGDs were to obtain feedback on the proposed CMMS model as to understand participants' views on the proposed CMMS, including any modifications or additional features they thought could improve the system. Besides that, understanding how important CMMS should integrate with existing PWD systems which was also highlighted during the session. The FGDs were used to pinpoint the most important effectiveness of asset management and maintenance processes. Participants were also asked to highlight potential challenges that could arise during the implementation of the CMMS and suggest strategies to overcome these hurdles.

The session was moderated and recorded for transcription and analysis purposes. Five expert practitioners from PWD Selangor participated, each representing different districts and roles related to the operation, maintenance, and management of road electrical assets. The background of panel role description are shown as Table 4.14.

Table 4.14  
FGD Panel Background Role Description

<b>Panel</b>	<b>Role</b>	<b>Description</b>
<b>Panel 1</b>	Senior Technical Lead for Traffic Light and Street Lighting Systems in Selangor	Over a decade of experience managing traffic light systems in Selangor, specializing in PLC, LED upgrades, and in-house repairs. Responsible for overseeing technical aspects, troubleshooting, and ensuring the efficiency of the traffic light systems.
<b>Panel 2</b>	District Electrical Engineer for Petaling	Leads a team of seven people, responsible for complaint management, field repairs, and electrical coordination within Klang District. Oversees the timely repair and maintenance of traffic lights and streetlights in the district.

<b>Panel 3</b>	District Engineer for Klang	Electrical	Manages electrical systems across a large urban area in Petaling, focusing on field deployment and coordination. In charge of the maintenance and troubleshooting of electrical systems like traffic lights and street lighting in the district.
<b>Panel 4</b>	Electrical Engineer		Responsible for the installation, operation, and maintenance of electrical systems for the whole Selangor. Focuses on budgetary planning, compliance with safety and regulatory standards. Provides support to senior staff and management oversees daily field operations in all districts.
<b>Panel 5</b>	Senior Engineer	Electrical	A senior leader with extensive experience in overseeing complex electrical systems. Head of maintenance not just road infrastructures but government buildings. Manages maintenance schedules, solves high-level technical challenges, and mentors junior engineers. Coordinates long-term planning and ensures the effective functioning of electrical assets across districts. Budgetary planning for the whole Selangor.

The panels represent a diverse set of roles and expertise, reflecting different levels of responsibility and knowledge within the Public Works Department (PWD) of Selangor. The relationship and the relevance of these panels in Focus Group Discussion were analysed to ensure relativity with Table 3.7 explained in previous chapter. Panel 1 serves as the Senior Technician Lead for Traffic Light and Street Lighting Systems in Selangor. This role is critical for overseeing the technical aspects of various traffic light systems, where the individual brings over a decade of experience in managing traffic light infrastructure, specializing in PLC, LED upgrades, and in-house repairs. This panellist is responsible for troubleshooting and ensuring the smooth operation of these systems. He is also aware of the technology trends and changes within the organization including the unified systems.

Panel 2, holding the role of District Electrical Engineer for Klang, takes on leadership within the district. In this position, the individual manages a team responsible for complaint management, field repairs, and electrical coordination within the district. This role is pivotal for ensuring the timely repair and maintenance of streetlights and traffic lights, highlighting the importance of technical oversight in day-to-day

operations. This individual is experienced in handling complaints and timely response, also having good insights through site observation and maintenance management.

Panel 3, another District Electrical Engineer but for Petaling, focuses specifically on the operational management of electrical systems. This individual is responsible for managing the deployment and coordination of field operations, including maintenance and troubleshooting electrical systems for Petaling, such as traffic lights and street lighting similar to Klang. This role is essential in overseeing the maintenance of electrical infrastructure in a large urban area like Petaling, ensuring that electrical operations run smoothly and efficiently. Fair experience on ground management or hands on with assets.

Panel 4 serves as an Electrical Engineer, with a broad responsibility across all of Selangor. This panellist's role is integral in overseeing the installation, operation, and maintenance of electrical systems throughout the state. They are tasked with ensuring compliance with safety standards and regulatory requirements, as well as supporting senior staff and management with reports and data. The position also involves budgetary planning and providing oversight of daily field operations across various districts.

Finally, Panel 5 the Senior Electrical Engineer, a senior leader with significant expertise in managing complex electrical systems. In this capacity, the individual is responsible for overseeing maintenance schedules, solving high-level technical challenges, and providing mentorship to junior engineers. This role also involves coordinating long-term planning for the maintenance of road infrastructures and government buildings across the districts of Selangor, with an emphasis on budgetary planning to ensure the optimal functioning of electrical assets.

The panels bring a wide range of expertise to the CMMS development process. The Electrical Engineer and Senior Electrical Engineer are responsible for guiding the overall strategy and overseeing the implementation of the systems at a higher level. On the other hand, the District Electrical Engineers focus on the day-to-day operations, ensuring that the system functions smoothly in the field or district. The Senior Technician, with their hands-on experience, offers valuable insights into how the system can be practically applied and ensure it works effectively in real-world scenarios. Together, these panels cover all the critical aspects of the CMMS and FGD, making sure that its questions and functionality are fully addressed.

#### **4.6.1 The FGD Flow & Sections:**

The respondents were first asked about their backgrounds, after which the panels were introduced to the structure of the session. The session was divided into three subsections: Unified Systems Overview, Technical Aspects of CMMS, and Complaint Resolution Analysis. Each panellist was given 7-10 minutes to answer the questions, allowing for an open and free-flowing discussion. The panels were informed that there were no right or wrong answers to the questions, encouraging them to engage in a candid conversation. The questions were framed as perspectives to be discussed rather than statements to agree or disagree with. They were also assured that the data collected during the session would not affect the organization's routine or reputation. The identities of the panellists were protected, and the session adhered to the university's research ethics guidelines. Each sections have two questions that were interviewed, and each panel have shared their input and experience.

The analysis began with manual coding using ATLAS.ti. Significant points raised by participants were highlighted and labelled with relevant phrases. These codes were then grouped into broader themes based on recurring topics and concerns expressed across the discussions. The software's query tool made it easier to extract direct quotes from the transcripts, tied to each code. For instance, a participant's remark like "We need real-time data access" was tagged under the theme Desired CMMS Features and included in the analysis accordingly.

Each theme reflected the actual feedback from participants, and the frequency with which certain topics were raised helped indicate their level of importance. For example, issues such as the need for maintenance data integration with REACT and real-time data access came up often, making them central themes in the analysis.

By tracking the repetition and depth of these themes, the study was able to highlight key aspects of PWD's current asset management process and identify how a CMMS could help improve it. The use of ATLAS.ti really supported this process by simplifying the tracking of themes and making it easier to connect participant insights back to the research objectives. Before diving into the individual themes, the main

thematic factors that emerged from the FGD questions were outlined. From 3 Sections, each having two sets of question, the theme was then identified then the theme was identified. Based on the diagram in Figure 4.3 below, the relationship between questions and theme was shown, hence highlighting the five themes.

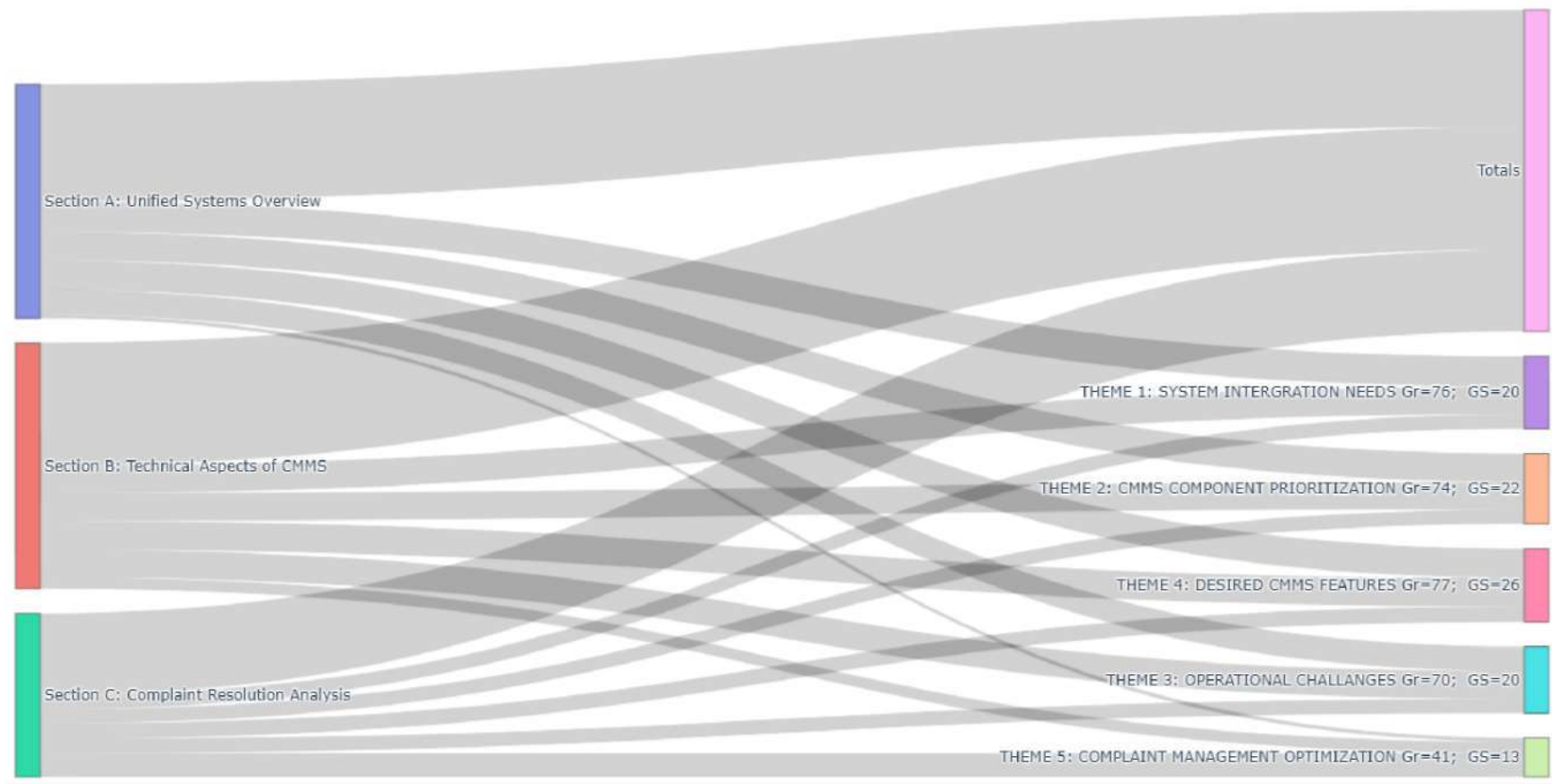


Figure 4.3 Sankey Diagram Relation of Section to Theme

The following Table 4.15 summarizes the primary themes identified:

Table 4.15  
Thematic Factors from the FGD

<b>Theme</b>	<b>Description</b>
<b>Theme 1: System Integration Needs</b>	The need for integrating maintenance information directly into the REACT system.
<b>Theme 2: CMMS Component Prioritization</b>	Prioritization of the key components of CMMS, such as maintenance management, asset management, and inventory control.
<b>Theme 3: Operational Challenges</b>	Challenges faced by PWD due to budget constraints, human resource limitations, and legacy infrastructure.
<b>Theme 4: Desired CMMS Features</b>	The features that participants believe would enhance the CMMS, such as QR code tracking, real-time data access, and battery/lifespan monitoring.
<b>Theme 5: Complaint Management Optimization</b>	Issues with the current complaint management system and how CMMS could streamline the process.

Each of these themes is explored in detail below, along with the frequency with which certain words or concepts were mentioned by participants. The thematic frequencies are calculated by examining how often participants referenced issues or features during the discussions. Based on the Sankey Diagram generated, the relationship between Themes and FGD session or section is shown in Figure 4.4. Each theme was taken input from an overall session, not biased through one session or section of the FGD.

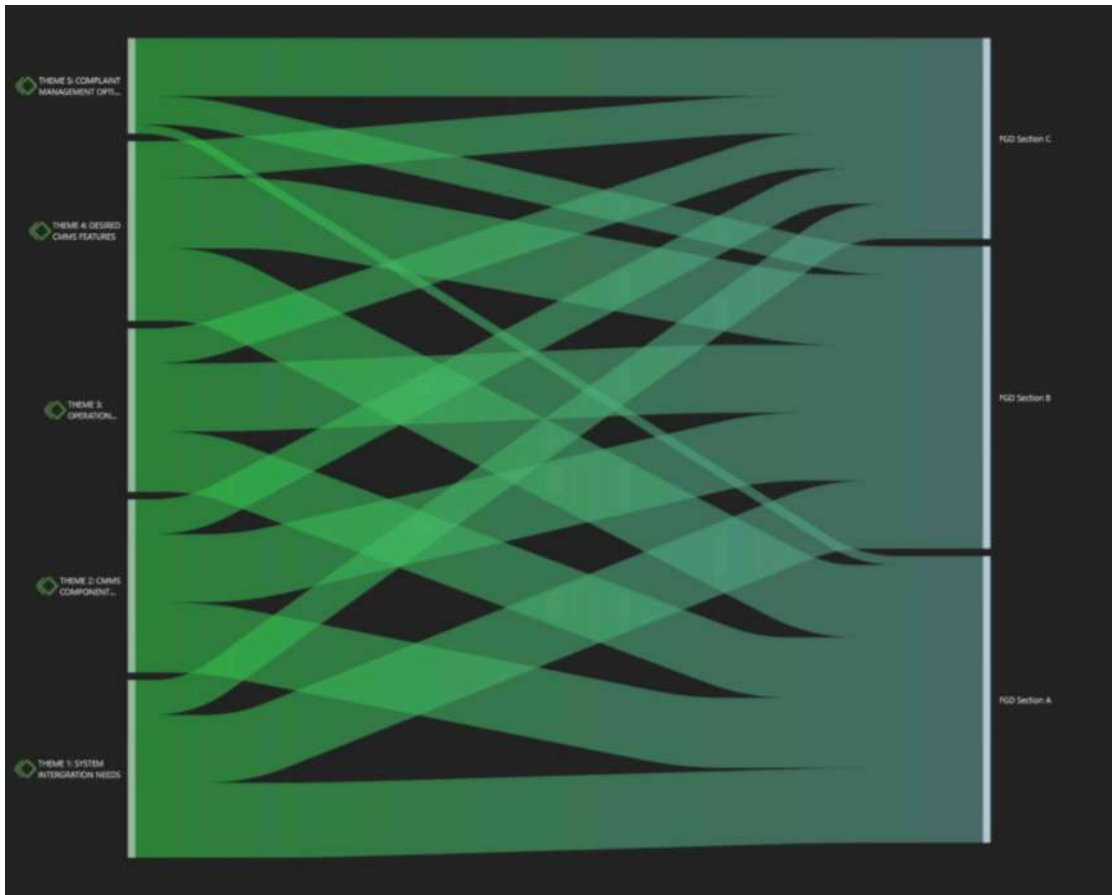


Figure 4.4 Sankey Diagram Relation of Theme with Section of FGD

Five major themes that were identified was cross map between each FGD sections. Each theme was group coded and analysed using ATLAS.ti, and the frequency and placement of these themes within the different FGD sections (A, B, and C) were mapped. The thickness of the connecting flows indicates the relative or frequency of each theme in the respective FGD sections shows a clear visual of which issues were most discussed and were.

From the diagram, it is clear that Operational Challenges and Desired CMMS Features were recurring topics across all sections, suggesting their importance and relevance to participants regardless of their roles or discussion context. In contrast, System Integration Needs appeared more prominently in FGD Section A, potentially indicating that participants in that group were more technically inclined or focused on backend systems. Similarly, Complaint Management Options and CMMS Components had varying levels of emphasis across the sections, reflecting the diversity of experiences and expectations among participants. This thematic mapping not only

highlights the core areas of concern for PWD during the session but also helps align future CMMS development with the most frequently voiced needs and challenges.

#### **4.6.2 Data Collection through ATLAS.ti**

In this qualitative research, making sense of large volumes of textual data requires a structured approach to uncover meaningful insights. In this study, the analysis followed a comprehensive method using four key tools within ATLAS.ti: Code Group Analysis, Code Document Analysis, Code Co-occurrence Analysis, and Theme Identification. These tools worked together to guide the thematic analysis, helping to break down complex discussions into clear, actionable findings that aligned with the study's objectives. Even though there are many other functions can be used in ATLAS, but these were the least that is relevant to be used.

The process analysis began with Code Group Analysis, where individual codes each representing a concept or recurring idea were organized into broader categories. The script was coded to context line by line. This helped to clarify which topics were most relevant and allowed the researcher to focus on key areas such as system integration, operational challenges, and maintenance management. By grouping related codes, such as those linked to system features or asset tracking, it became easier to see where discussions concentrated and how the participants viewed various aspects of the CMMS.

Next, Code Document Analysis linked these codes back to specific sections of the focus group transcripts. This step made it possible to examine how often certain themes appeared and where they were discussed most prominently. For example, the "System Integration" code appeared frequently in conversations about current system limitations, revealing how central this issue was to participants across different sessions. This approach ensured that the frequency and placement of themes were grounded in the actual data and the frequency of codes to appear in each section.

The third step, Code Co-occurrence Analysis, examined how different codes appeared together in the same parts of the discussion. This helped uncover relationships between ideas that might not have been obvious at first. For instance, frequent overlap between "Asset Management" and "Work Order Management" highlighted how closely

these two functions are linked, suggesting that improvements in one area would likely impact the other. These patterns provided a deeper understanding of how different components of the CMMS are interconnected.

Together, these three steps offered a structured yet flexible approach to analysing qualitative data. The tools in ATLAS.ti supported the researcher in making sense of complex discussions, ensuring that the resulting themes were both grounded in the data and useful for informing system development. This process provided a clear path from raw participant input to well-defined insights that can support decision-making and system design.

#### ***4.6.2.1 Theme 1: System Integration Needs***

The System Integration Needs theme emerged from the discussions regarding the limitations of the current REACT platform, specifically the lack of integrated maintenance data. The Panels expressed a strong desire to incorporate maintenance-related data directly into REACT rather than keeping it as a separate, stand-alone system. The current system is largely used for monitoring the functionality of electrical assets, but it does not provide the necessary tools to effectively track maintenance needs or manage the lifecycle of assets. This theme is pivotal, as it underscores the need for a more holistic approach to asset management, one that incorporates both monitoring and maintenance functions seamlessly. Figure 4.5 below shows the relationship between each code made from the context and related to this theme.

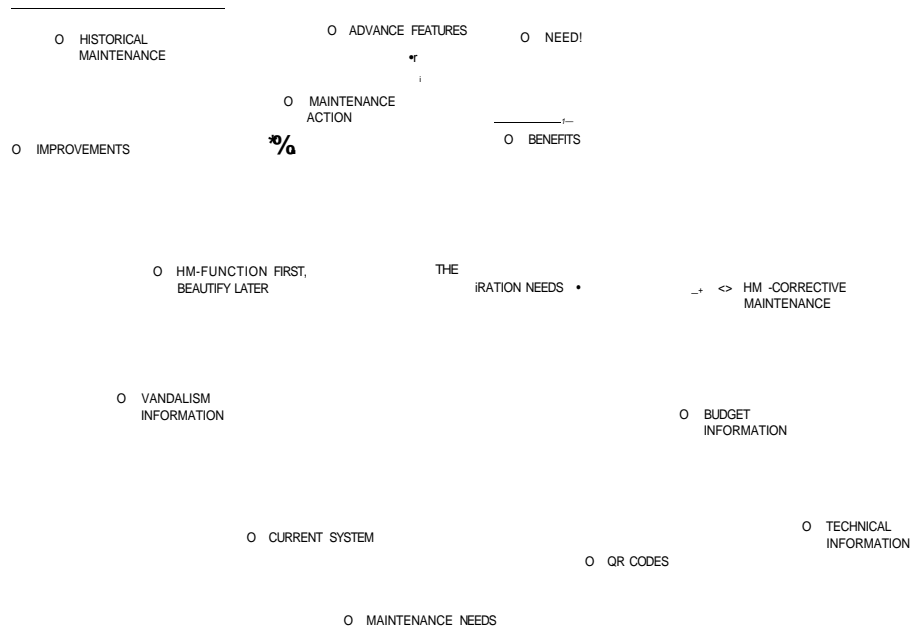


Figure 4.5 Code Diagram Relation of Theme 1 with Section of FGD

#### Data and Analysis:

The Code Co-occurrence Analysis revealed a significant relationship between the codes System Integration and Maintenance Management, which frequently appeared together across the focus group discussions. This co-occurrence highlights a clear gap in the REACT system, where maintenance data integration is seen as critical for proactive asset management. For example, Panel 2 pointed out, "REACT is primarily a data collection system... but adding maintenance features would be beneficial," indicating the limitations of the current system in supporting maintenance planning and decision-making.

Table 4.16

#### System Integration Needs - Codes Related

Num	Quote	Coding Related
1	Panel 2: Yes, that's right. Vendors usually give a 5-year lifespan for batteries. If REACT can display that information, we'd know when to replace them.	Current System Improvements Technical Information

- 2 Panel 2: Current System  
 From what I know, REACT functions like a modem - it collects data, has storage, and connects to the cloud for system automation. It features sensors such as loop sensors, wireless vehicle detectors, radar, and AI cameras to optimize traffic flow. In the past, systems like SCOOT used loop sensors to count vehicles and coordinate traffic. With AI today, adjustments can be made in real time based on traffic conditions, saving time and making traffic smoother.
- 3 Panel 3: Current System  
 Right now, we only know whether the system is working or not. We don't know the reasons behind failures. That's what's missing. We need to add more elements to REACT. Since it only tells us "working" or "not working," our response is delayed. Improvements
- 4 Panel 2: Benefits  
 The benefit is, with REACT and AI cameras, we can gather traffic statistics, identify vehicle types, and monitor problematic vehicles—so we don't need to conduct physical traffic counts anymore. Current System
- 5 Panel 1: Past Systems  
 Back in 2012-2013, before REACT, we used an SMS-based system. For example, if someone opened a TNB service door, we would receive a notification about unauthorized access or theft. We kept upgrading the system until we got to REACT, which has been very helpful in monitoring our JKR assets. Need of CMMS
- 6 Panel 5: Improvements  
 If you ask me for advice, yes—it's essential. Having this integration helps with our monitoring efforts. Need of CMMS

Ideally, we should be able to click on one platform and immediately see whether an asset is due for maintenance.

7	<p>Panel 4:</p> <p>My expectations for REACT were high. For example, I imagined pressing a button and instantly seeing the light's battery level or confirming if it's functioning. But those features are not there. So yes, I would say it's lacking.</p>	<p>Current System Improvements Need of CMMS</p>
8	<p>Panel 2:</p> <p>In Klang, we're not yet at the stage where we can fully benefit from REACT. A lot of our equipment is still old. It's better if we focus on upgrading to newer controllers first.</p>	<p>Current System Expectation Practice</p>
9	<p>Panel 5:</p> <p>I agree. For older systems, just leave them as they are. Focus on upgrading and integrating the new systems into REACT. It's more cost-effective that way.</p>	<p>Benefits Expectation Improvements Need Of CMMS</p>
10	<p>Panel 3:</p> <p>If it's a new asset, integration is fine.</p>	<p>Current System Improvements</p>

The table summarizes the main frequency and context of key codes related to System Integration Needs. It reflects the recurring concern among panels about the lack of maintenance integration in the existing REACT platform and emphasizes the importance of having real-time data on asset conditions for efficient management.

**4.6.2.2 Theme 2: CMMS Component Prioritization**

The second theme identified in the thematic analysis focuses on the prioritization of CMMS components. This theme highlights the panels' views on which aspects of a Computerized Maintenance Management System (CMMS) should be prioritized for successful implementation. In the FGDs, the panels discussed the various

components of CMMS, including Work Order Management, Asset Management, Maintenance Management, Inventory Control, and Reporting Management. The discussions revealed a consensus that certain components should take precedence based on the current challenges faced by the Public Works Department (PWD).

The analysis indicates that Maintenance Management was viewed as the most critical component, followed by Asset Management and Inventory Control. Participants emphasized the importance of efficient maintenance scheduling, tracking asset conditions, and ensuring that the necessary parts and materials are readily available for repairs. These components were seen as essential for minimizing downtime and extending the lifespan of road electrical assets. Figure 4.6 shows Theme 2 relationship with coding in context.

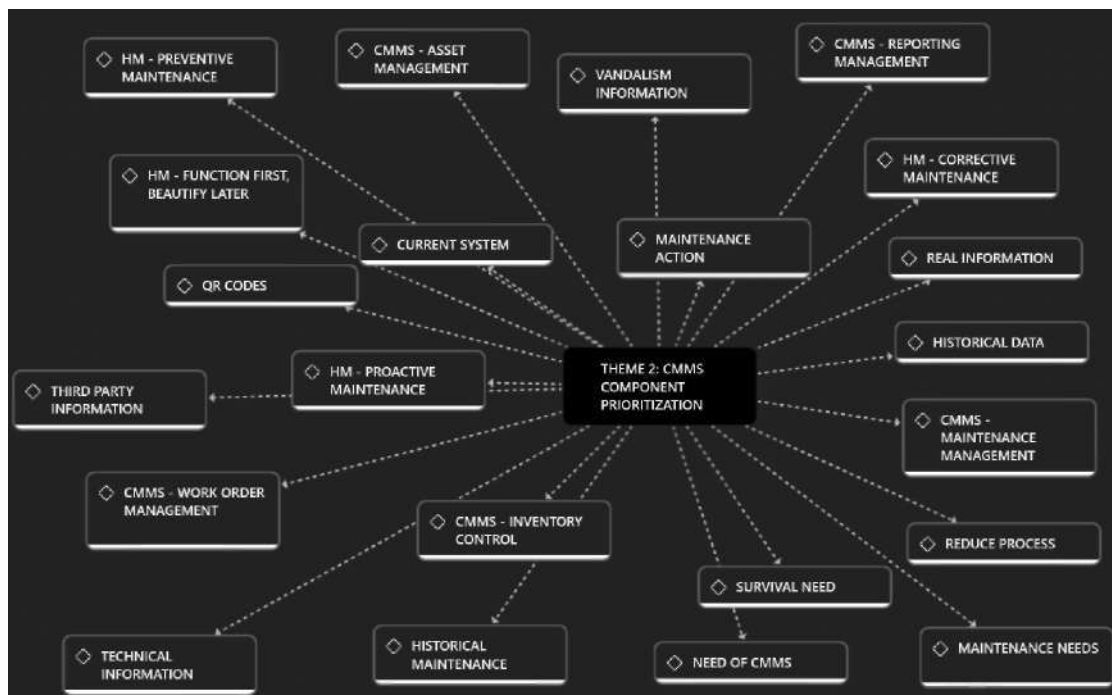


Figure 4.6 Code Diagram Relation of Theme 2 with Section of FGD

#### Data and Analysis:

The co-occurrence analysis identified that Maintenance Management and Asset Management were frequently linked, underscoring their interdependent nature. For example, Panel 2 stated, "Maintenance management is crucial. Without it, we're just reacting, not preventing issues." This reflects the participants' view that effective

maintenance practices must be informed by accurate and up-to-date asset data. Similarly, Inventory Control was often mentioned alongside Work Order Management, indicating that having the right parts available is essential for executing maintenance tasks efficiently.

Table 4.17

CMMS Component Prioritization - Codes Related

Num	Quote	Coding Related
1	<p>Panel 2: In my experience, for cabling -1 would say maintenance management.</p>	<p>CMMS - Maintenance Management Maintenance Action Maintenance Needs Need Of CMMS</p>
	<p>Panel 3: That's right. If maintenance management is already efficient, then the rest should follow smoothly.</p>	<p>CMMS - Maintenance Management Need Of CMMS Technical Information</p>
	<p>Panel 4: If I put myself in this situation, I would say the most important is asset management. Because, say at night, if a state electrical director or top management asks which lamp is out—we don't have the exact location. Our assets are not well managed. Even if someone shares a picture of a pole, I still have to refer to the district OIC (officer in charge) to confirm whether it's ours.</p>	<p>CMMS - Asset Management Complaint Sources Current System Technical Information</p>

Panel 4: Challenges  
Sometimes, even the OIC isn't sure. Same with CMMS - Asset  
feeder pillars—if TNB calls about unpaid bills, I Management  
don't even know if the meter belongs to us or the Current System  
local council. There's no tagging system. So if Expectation  
you ask me, the most important is asset Scattered Information  
management.

Panel 5: Challenges  
I can see the problem now—assets are not listed Expectation  
in inventory. If the director or district engineer Vandalism Information  
asks, "How many lamps are there in Hulu  
Langat?"D—we can't answer. I once suggested  
having a workshop, maybe in Langkawi where  
we won't be disturbed. I see that as critical.

Panel 5: CMMS - Inventory  
We can't even access how many lights we have. Control  
So asset and inventory management are more  
important. From asset data, we'd know when it  
was installed. For example, if something starts to  
fail in year five, we'd understand why. But for  
someone like me, who just joined a year ago, I  
have no idea when assets were installed. Now  
solar units are starting to fail, but there's no  
baseline info.

Panel 5: CMMS - Maintenance  
It's easier to manage if it's not just a single Management  
component. From my higher-level view, I'd say Expectation  
asset management is most important. But the Maintenance Action  
frontliners—the ones on the ground—will  
prioritize maintenance because that's what they

deal with. Everyone has different scopes and constraints.

Maintenance Needs  
Scattered Information

Panel 3:  
Asset management could be the top component, and the others can fall under it.

CMMS - Asset  
Management  
Current System  
Real Information

Panel 1:  
For example, in Petaling, we took over work from PLUS. On FT02 Federal Highway, many of the cables are still from the 1980s, and they're still in use. So, aside from vandalism, the main factor is aging infrastructure—it needs replacement.

Budget Constraint  
Challenges  
Current System  
Expectation  
Improvements  
Maintenance Action  
Maintenance Needs  
Need of CMMS  
Past Systems  
Real Information  
Technical Information  
Third Party Information  
Vandalism Information

10 Panel 2:  
The complaints we receive are mostly about non-functioning signals—green or amber not lighting up. Faults like LEDs not lighting, timing issues, phasing, or fault timing. If there's damage, the system will log it under fault time. Most public complaints just report whether it works or not, or whether bulbs are out. A single

Challenges  
Complaint Sources  
Current System  
Expectation  
Maintenance Action  
Maintenance Needs  
Practice

intersection has 4 indicators—2 primary, 2 secondary. Sometimes overhead lights, left, right, lower sides. Overseas, they don't have as many aspects as we do. If one side is hit, we still have other sides working—until only one remains.

Real Information  
Technical Information

This table summarizes the frequency of key codes related to the CMMS Component Prioritization theme. The high frequency of Maintenance Management reflects its importance among the panels. Asset Management and Inventory Control were also frequently discussed, highlighting their role in facilitating efficient maintenance workflows.

#### 4.6.2.3 Theme 3: Operational Challenges

The third theme when identified in the thematic analysis revolves around Operational Challenges, which were highlighted by the panels as key barriers to the successful implementation and functioning of a Computerized Maintenance Management System (CMMS). The discussions revealed that several operational factors, including Budget Constraints, Human Resource Limitations, and Field Delay Factors, significantly impact the current maintenance operations and hinder the ability to effectively manage road electrical assets. These challenges have direct implications for the adoption and efficiency of CMMS solutions.

The panels expressed a clear awareness of the constraints they face, with a particular focus on the budget allocated to maintenance projects and the human resources available to carry out the necessary work. These limitations result in delays in addressing maintenance needs and can cause significant inefficiencies. The theme also included discussions on legacy infrastructure, where outdated systems or components further complicate the integration of new technologies, such as a CMMS, into existing operations. Figure 4.7 shows coding parameter related to the Theme 3 operational challenges.

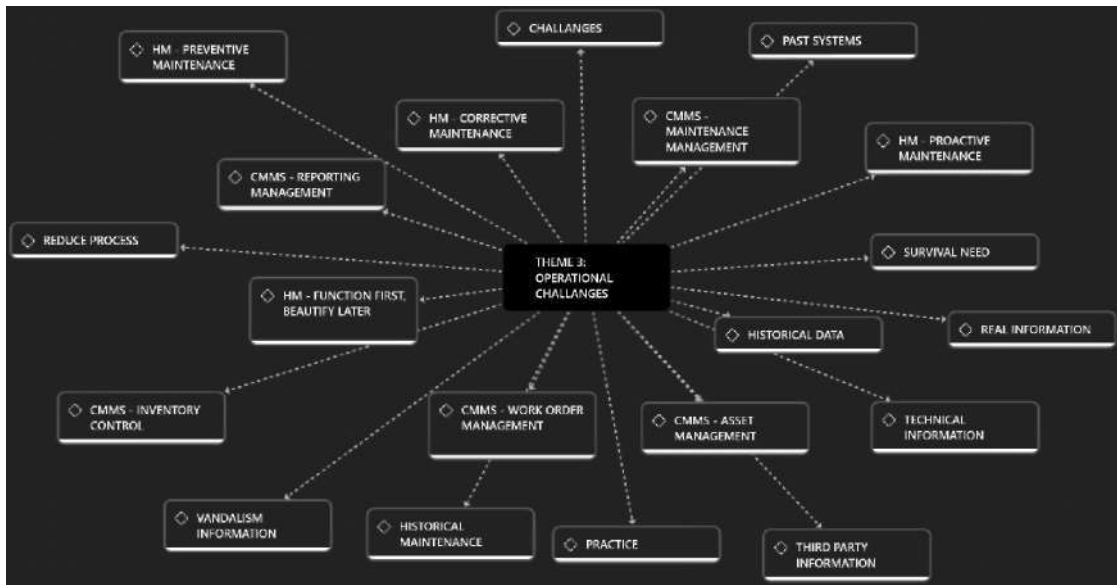


Figure 4.7 Code Diagram Relation of Theme 3 with Section of FGD

Data and Analysis:

From the Code Co-occurrence Analysis, it became evident that Budget Constraints and Human Resource Limitations were frequently discussed together. This co-occurrence suggests that financial and staffing shortages are perceived as the most pressing issues that prevent the effective implementation of CMMS solutions. For example, Panel 1 pointed out, "We have aspirations to improve the system, but the funding is not sufficient to make the changes we need," highlighting the ongoing challenge of limited financial resources.

Similarly, Field Delay Factors, such as difficulties in accessing certain sites or unforeseen delays in maintenance tasks, were often mentioned in conjunction with Human Resource Limitations. This reflects the operational difficulty of maintaining adequate staffing levels and having the necessary personnel available to handle urgent issues. Panel 4 stated, "We are not on standby, but when we receive a call, we must respond, even if it's after hours," emphasizing the strain on human resources when maintenance issues arise unexpectedly.

Table 4.18

Operational Challenges -Codes Related

<b>Num</b>	<b>Quote</b>	<b>Coding Related</b>
	<p>Panel 3:</p> <p>Right now, we only know whether the system is working or not. We don't know the reasons behind failures. That's what's missing. We need to add more elements to REACT. Since it only tells us "working" or "not working," our response is delayed.</p>	<p>Current System</p> <p>Improvements</p> <p>Technical Information</p>
	<p>Panel 2:</p> <p>The benefit is, with REACT and AI cameras, we can gather traffic statistics, identify vehicle types, and monitor problematic vehicles—so we don't need to conduct physical traffic counts anymore.</p>	<p>Benefits</p> <p>Current System</p>
	<p>Panel 5:</p> <p>Ideally, we should be able to see voltage levels for each phase, current flow, and any abnormalities. If the system shows that, we can already anticipate what kind of issue might be happening on site. Also, we should be able to track the lifespan of each component like lanterns or solar panels.</p>	<p>Benefits</p> <p>Expectation</p> <p>Improvements</p> <p>Technical Information</p>
	<p>Panel 1:</p> <p>We have plans, but federal budget constraints make it hard to get everything we want.</p>	<p>Budget Constraint</p> <p>Budget Information</p> <p>Practice</p>
	<p>Panel 2:</p> <p>If we have the budget, even the most</p>	<p>Advance Features</p> <p>Budget Constraint</p>

advanced features can be realized.  
Management can also easily calculate the total cost.

Budget Information  
Expectation

Panel 4:  
It would help a lot. Let's say I receive a complaint and I call Panel 2 about a problem at a roundabout. If he says it's raining and suspects a trip or leakage—we can verify that based on history. If this has happened before, we can identify the pattern. We'd know the answer on the spot without waiting for site results or inspections.

Benefits  
Complaint Repitition  
Historical Data  
Historical Maintenance  
Hm - Corrective  
Maintenance  
Hm - Preventive  
Maintenance  
Hm - Proactive  
Maintenance  
Maintenance Action  
Maintenance Needs  
Technical Information

Panel 3:  
Let me give an example. A complaint logged today (let's say May 5th) only reached me on May 15th. So yes, there's a delay.

Complaint Management  
Complaint Sources  
Conflict Channels  
Customer Charter  
Delayed Complaints

Panel 2:  
The reasons are simple. We just don't have enough staff or budget. In my area, the more advanced features are probably better suited for other districts.

Expectation

9	Panel 2: For traffic lights, we're required to resolve issues within 24 hours.	Customer Charter Practice
10	Panel 1: That's why if REACT could notify us about issues before complaints are made, it would be ideal.	Benefits Expectation Improvements Maintenance Action Maintenance Needs Need Of CMMS Real Information Technical Information

This table summarizes the frequency and context of key codes related to Operational Challenges. The high frequency of Budget Constraints and Human Resource Limitations reflects the importance of these factors in the panels' discussions. Field Delay Factors, while discussed less frequently, still represent a significant barrier to operational efficiency.

**4.6.2.4 Theme 4: Desired CMMS Features**

The fourth theme identified in the thematic analysis revolves around the Desired CMMS Features as expressed by the panels during the focus group discussions. This theme highlights the specific functionalities and capabilities that the participants consider essential for a Computerized Maintenance Management System (CMMS) to be successful in the context of road electrical asset management. The panels outlined a range of features that would make the CMMS more effective, including QR Code Tracking, Real-Time Data Access, Battery and Lifespan Monitoring, and Vandalism Alerts / Tampering Detection.

Each of these features was viewed as critical for improving the overall efficiency and effectiveness of maintenance operations. The Real-Time Data Access feature, for example, was frequently discussed as essential for allowing maintenance teams to

respond quickly to issues and make informed decisions. Similarly, QR Code Tracking was seen as a simple yet effective method for monitoring asset conditions and ensuring that all assets are accounted for in real-time. Other features, such as Battery and Lifespan Monitoring, were seen as necessary for extending the life of assets and ensuring that they are replaced before they fail, while Vandalism Alerts were viewed as crucial for detecting and responding to damage caused by third parties.

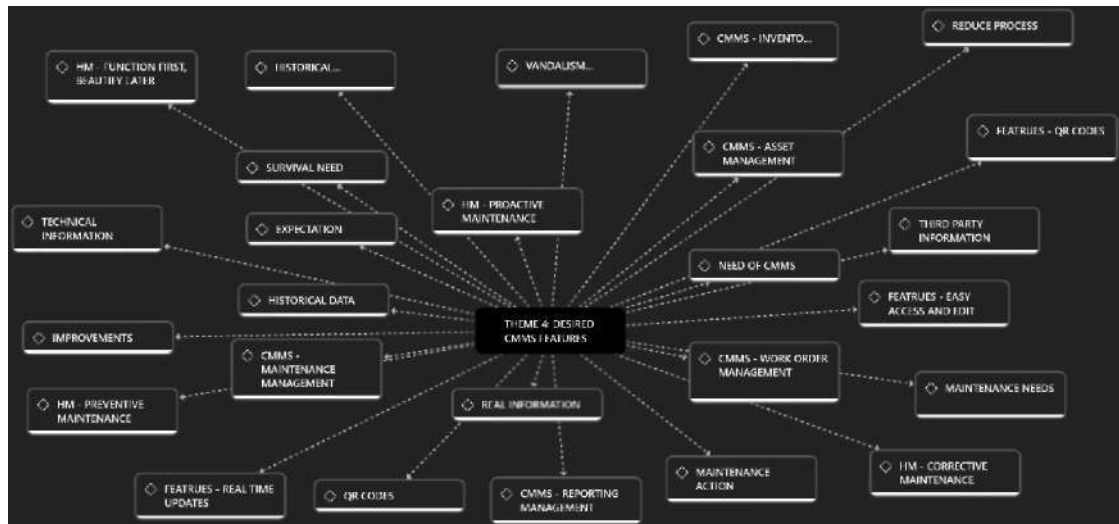


Figure 4.8 Code Diagram Relation of Theme 4 with Section of FGD

Data and Analysis:

The Code Co-occurrence Analysis revealed that the features of Real-Time Data Access and Predictive Maintenance often co-occurred, indicating that panels saw these features as highly interdependent. For example, Panel 3 mentioned, "Having real-time data about asset conditions would allow us to act sooner and more effectively," highlighting the need for access to up-to-date information for proactive decision-making. Similarly, QR Code Tracking was frequently mentioned alongside Asset Management and Inventory Control, suggesting that the ability to track assets in real-time is essential for ensuring efficient maintenance and inventory management.

Table 4.19

Desired CMMS Features - Codes Related

Num	Quote	Coding Related
-----	-------	----------------

- |   |   |                            |
|---|---|----------------------------|
| 1 | <p>Panel 2:</p> <p>From what I know, REACT functions like a modem - it collects data, has storage, and connects to the cloud for system automation. It features sensors such as loop sensors, wireless vehicle detectors, radar, and AI cameras to optimize traffic flow. In the past, systems like SCOOT used loop sensors to count vehicles and coordinate traffic. With AI today, adjustments can be made in real time based on traffic conditions, saving time and making traffic smoother.</p> | Current System             |
| 2 | <p>Panel 2:</p> <p>The benefit is, with REACT and AI cameras, we can gather traffic statistics, identify vehicle types, and monitor problematic vehicles—so we don't need to conduct physical traffic counts anymore.</p>   | Benefits<br>Current System |
| 3 | <p>Panel 1:</p> <p>Back in 2012-2013, before REACT, we used an SMS-based system. For example, if someone opened a TNB service door, we would receive a notification about unauthorized access or theft. We kept upgrading the system until we got to REACT, which has been very helpful in monitoring our JKR assets.</p>   | Past Systems               |

Panel 2:	Advance Features
For me, the best way to integrate with REACT	Current System
is through AI cameras. That's most important	Expectation
to me because it already includes loop	Historical Data
sensors, wireless vehicle detectors, and	Improvements
infrared.	Real Information
	Technical Information
	Third Party Information

Panel 4:	Advance Features
I agree with that. Budget is key. The simplest	Benefits
would be QR code stickers—you scan and	Budget Constraint
instantly get location, district, installation	Budget Information
date, key-in date—just like what TNB does.	Expectation
But to do that requires a system and internet—	Historical Data
so again, budget.	Improvements
	Maintenance Action
	Maintenance Needs
	Real Information
	Technical Information

A key feature should be real-time information.	CMMS - Asset
If you use QR codes, what information is	Management
shown must be real-time. All districts in	CMMS - Inventory
Selangor need to update their lamp counts. So	Control
when management asks, the system can give	CMMS - Reporting
real-time answers.	Management
	Expectation
	Improvements
	Real Information

	Panel 5:	CMMS - Asset Management CMMS - Maintenance Management Improvements Real Information
	Yes, that's the kind of info we need. Real-time updates are a must when developing CMMS. Upper management always wants info immediately.	
	Panel 4:	Current System Improvements Need Of CMMS
	My expectations for REACT were high. For example, I imagined pressing a button and instantly seeing the light's battery level or confirming if it's functioning. But those features are not there. So yes, I would say it's lacking.	
	Panel 2:	Current System Improvements Technical Information
	Yes, that's right. Vendors usually give a 5-year lifespan for batteries. If REACT can display that information, we'd know when to replace them	
10	Panel 2:	Advance Features Budget Constraint Budget Information Expectation
	If we have the budget, even the most advanced features can be realized	

This table illustrates the frequency of key codes related to the Desired CMMS Features theme. The high frequency of Real-Time Data Access underscores its importance, while QR Code Tracking and Vandalism Alerts also emerged as essential features for improving asset management and ensuring quick responses to damage or failure.

#### ***4.6.2.5 Theme 5: Complaint Management Optimization***

The fifth theme identified in the thematic analysis focuses on Complaint Management Optimization. This theme highlights the challenges and opportunities in improving the current process of handling and resolving complaints related to road electrical assets. Throughout the focus group discussions (FGDs), the panels emphasized the importance of streamlining the complaint management system to reduce response times, eliminate unnecessary steps, and ensure faster, more effective resolution. The theme revolves around optimizing the existing complaint management workflow, which is crucial for improving operational efficiency and customer satisfaction.

The current complaint management process, as discussed by the panels, often suffers from delays due to hierarchical structures, inadequate data tracking, and communication inefficiencies. The Complaint Management Optimization theme focuses on addressing these issues through the integration of more efficient processes and technology, particularly through the implementation of a Computerized Maintenance Management System (CMMS). By improving this system, the panels aim to reduce the time it takes to respond to and resolve complaints, thereby enhancing the overall asset management system. Through this theme, even though less coding is related in the theme as shows in Figure 4.9 below, compared to other themes, but it stays relevant as it is supported with the simulation or objective number 2.

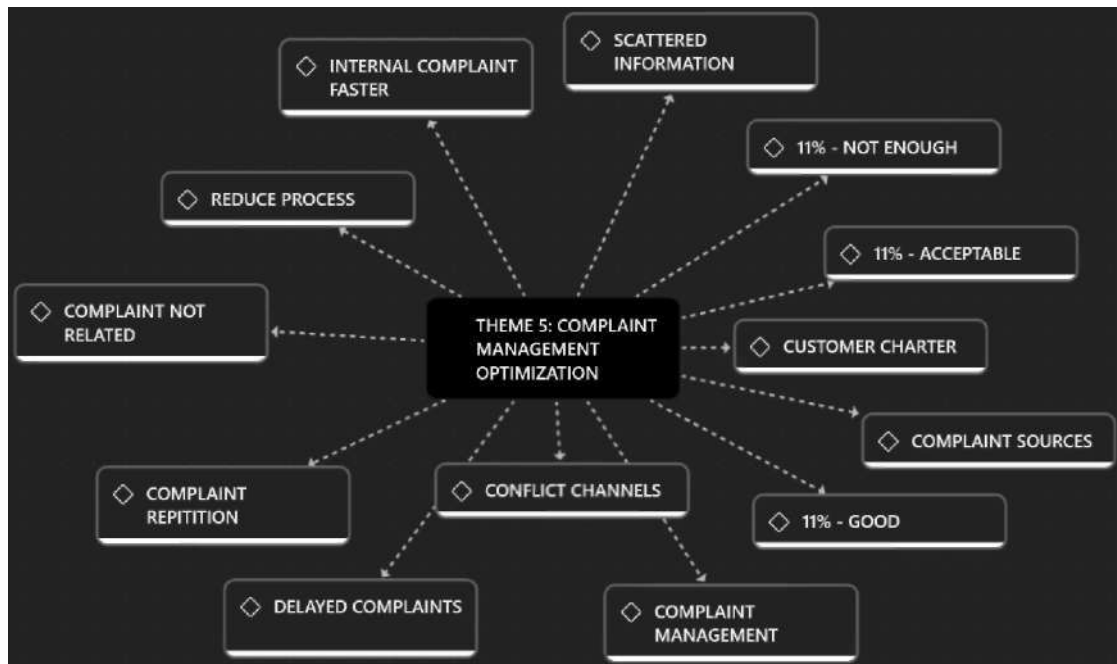


Figure 4.9 Code Diagram Relation of Theme 5 with Section of FGD

#### Data and Analysis:

From the Code Co-occurrence Analysis, it became clear that Complaint Delay Factors and Hierarchy Reduction were frequently discussed together, indicating that delays in complaint resolution were often due to unnecessary hierarchical steps in the process. As Panel 3 mentioned, "If we could reduce two hierarchical steps, we could save at least one day in the complaint resolution process." This sentiment was echoed by several other panels, who identified Complaint Delay Factors as a significant obstacle to improving response times.

Additionally, Historical Maintenance Access was highlighted as a crucial factor in diagnosing and resolving complaints more efficiently. The ability to access historical maintenance data was seen as an important tool for quickly identifying recurring issues and predicting potential failures. For example, Panel 5 stated, "Having access to historical records would allow us to diagnose issues much faster and prevent recurring problems." This is an essential aspect of optimizing the complaint management process, as it would enable faster decision-making and more accurate responses to complaints.

Table 4.20

Complaint Management Optimization - Frequency of Codes

Num	Quote	Coding Related
Panel 4:	Exactly. For new assets, we fully agree. They can be registered in the system immediately, and we'll be able to tell exactly when they fail. That would help a lot.	Current System Maintenance Needs Practice
Panel 4:	Right now, we often rely on public complaints, and sometimes they're not even accurate. With maintenance integration, we can confirm from the system if a light is truly not working instead of wasting time investigating a false complaint.	Benefits Expectation Improvements Maintenance Needs NeedOfCMMS Practice
Panel 2:	Right now, we get complaints from many different places.	Complaint Sources
Panel 4:	11%? Hmm. 11% is okay, but not enough in my opinion. Maybe we could eliminate two or three more steps.	11 % - Not Enough Reduce Process
Panel 3:	Let me give an example. A complaint logged today (let's say May 5th) only reached me on May 15th. So yes, there's a delay.	Complaint Management Complaint Sources Conflict Channels Customer Charter Delayed Complaints

	Panel 3:	Challenges
	Sometimes we can't even access the site at the reported time.	Current System
		Past Systems
		Technical Information
		Third Party Information
	Panel 2:	Customer Charter
	For traffic lights, we're required to resolve issues within 24 hours.	Practice
	Panel 1:	Maintenance Action
	Once there's a complaint, we have to attend to it—no matter what.	Maintenance Needs
		Practice
	Panel 1:	Benefits
	That's why if REACT could notify us about issues before complaints are made, it would be ideal.	Expectation
		Improvements
		Maintenance Action
		Maintenance Needs
		NeedOfCMMS
		Real Information
		Technical Information
10	Panel 4:	Complaint Management
	Exactly. If the complaint goes straight to the District Engineer of Klang, it's faster. If it goes through JKR Selangor, it loops around first.	Complaint Sources
		Conflict Channels
		Internal Complaint Faster
		Reduce Process
		Scattered Information

This table summarizes the frequency of key codes related to Complaint Management Optimization. The high frequency of Complaint Delay Factors and Hierarchy Reduction reflects the panels' strong focus on improving the speed and

efficiency of the complaint resolution process. The code Historical Maintenance Access was also frequently discussed, emphasizing the importance of leveraging past data to optimize future actions.

### 4.6.3 Outcome of Themes

Understanding the critical factors influencing the implementation of a Computerized Maintenance Management System (CMMS) for road electrical asset management from the discussion will help to prioritize strategic needs and operational gaps for the unified system.

Table 4.21

Desired State and Expected Impact Table

<b>Num</b>	<b>Theme Title</b>	<b>Main Problem Identified</b>	<b>Desired State</b>	<b>Key CMMS Contribution</b>	<b>Expected Impact</b>
<b>1</b>	System Integration Needs	REACT lacks integrated maintenance capabilities	Single platform for monitoring & maintenance	Integrate asset condition, repair history, predictive maintenance	Faster decision-making, longer asset lifespan
<b>2</b>	CMMS Component Prioritization	Reactive maintenance approach	Prioritised modules (Maintenance Management then Asset Management then Inventory)	Proactive scheduling, complete asset records, spare parts readiness	Reduced downtime, optimised resources
<b>3</b>	Operational Challenges	Budget, HR, site delays, outdated infrastructure	Resource & capacity improvements	Phased CMMS rollout with targeted investments	Feasible, sustainable implementation

4	Desired CMMS Features	Limited monitoring scope	Predictive and real-time maintenance tools	Real-time data, QR tracking, lifespan monitoring, vandalism alerts	Reduced failures, faster response, asset protection
5	Complaint Management Optimization	Slow complaint resolution, lack of history	Streamlined, data-driven process	Fewer approval layers, historical data access	11% faster resolution, fewer repeat issues

#### ***4.6.3.1 Outcome of the Theme Analysis 1***

The analysis of System Integration Needs indicates that the REACT system, in its current state, is not sufficiently equipped to support integrated maintenance management. The need for seamless integration between maintenance and monitoring functions was consistently highlighted across the discussions. The panels were unanimous in their view that incorporating maintenance-related data, such as asset conditions, repair histories, and lifespan data, into the system would significantly enhance operational efficiency.

Furthermore, the absence of maintenance integration was seen as a barrier to proactive maintenance management. Instead of reacting to issues as they arise, integrating predictive maintenance capabilities would allow for more informed decision-making and timely interventions. This finding emphasizes the need for a CMMS (Computerized Maintenance Management System) that not only monitors assets in real-time but also tracks maintenance data and schedules, ultimately improving the longevity and performance of road electrical assets.

Addressing the System Integration Needs theme is essential for enhancing the REACT system. A more integrated approach would not only streamline operations but also improve asset management practices, making it easier to predict failures and schedule maintenance tasks efficiently. This theme paves the way for the further exploration of the features necessary in a CMMS and its integration with existing systems.

#### ***4.6.3.2 Outcome of the Theme Analysis 2***

The CMMS Component Prioritization theme reveals that the panels strongly believe that Maintenance Management is the most important component to prioritize in the development of a CMMS. This emphasis on Maintenance Management reflects the challenges currently faced by the Public Works Department (PWD) in managing maintenance activities in a reactive manner. Panels stressed the need for a system that not only tracks asset conditions but also enables proactive maintenance scheduling to prevent failures before they occur.

Additionally, Asset Management and Inventory Control were identified as critical components that should be integrated into the CMMS. Effective Asset Management ensures that accurate information about the health of each asset is readily available, while Inventory Control ensures that the necessary parts and materials are available when required for repairs. Together, these components form the backbone of a CMMS that can optimize maintenance operations and improve asset management.

This theme also highlights the participants' desire for a system that is comprehensive yet flexible, allowing for the prioritization of certain components based on operational needs and resource constraints. In conclusion, prioritizing Maintenance Management, followed by Asset Management and Inventory Control, would ensure that the CMMS addresses the most immediate operational challenges and enhances the overall efficiency of road electrical asset management.

#### ***4.6.3.3 Outcome of the Theme Analysis 3***

The Operational Challenges theme highlights the significant barriers that prevent the successful implementation of CMMS in the context of road electrical asset management. Budget Constraints were identified as a critical issue, with panels noting that the lack of sufficient financial resources prevents the adoption of advanced technologies, including CMMS, and limits the capacity for necessary system upgrades. Human Resource Limitations further compound the issue, as a shortage of staff or inadequate training makes it difficult to carry out maintenance tasks efficiently, especially during emergencies or outside of regular working hours.

Field Delay Factors, such as the difficulty in accessing maintenance sites in a timely manner, also emerged as a key operational challenge. These delays are often compounded by logistical issues or unforeseen circumstances, making it difficult to ensure that assets are maintained promptly and effectively. Additionally, Legacy Infrastructure was mentioned as a challenge, with participants noting that outdated equipment and systems create further complications when attempting to integrate new technologies like CMMS into the existing infrastructure.

The analysis of this theme underscores the importance of addressing these operational challenges as part of any CMMS implementation plan. To successfully adopt a CMMS, the Public Works Department (PWD) must consider strategies to overcome these barriers, such as securing additional funding, improving resource allocation, and providing adequate training to staff. The Operational Challenges theme emphasizes the need for a practical, phased approach to CMMS implementation that takes these constraints into account, ensuring that the system is not only effective but also feasible within the current operational landscape.

#### ***4.6.3.4 Outcome of the Theme Analysis 4***

The Desired CMMS Features theme reveals a strong consensus among the panels regarding the need for specific features in the proposed CMMS. Real-Time Data Access emerged as one of the most critical features, as it would allow maintenance teams to access up-to-date information on asset conditions, enabling more timely and effective decision-making. QR Code Tracking was also highlighted as a key feature for asset management, as it provides a simple yet powerful way to track the location and condition of assets in real-time.

Additionally, the inclusion of Battery and Lifespan Monitoring was seen as vital for ensuring that assets such as batteries, which have a limited lifespan, are replaced before they fail. This feature would enable more proactive maintenance, reducing the likelihood of unexpected failures. Vandalism Alerts, such as using CCTV and sensors to detect third-party damage, were also considered important for protecting infrastructure and ensuring the safety of road electrical assets.

The analysis of this theme emphasizes that the features participants consider most important for the CMMS revolve around proactive maintenance, real-time asset tracking, and damage detection. These features are essential for improving the efficiency and effectiveness of maintenance operations, allowing the Public Works Department (PWD) to respond quickly to emerging issues and extend the lifespan of critical assets. Furthermore, the inclusion of these features will contribute to a more integrated and streamlined system that can effectively manage road electrical assets in a way that reduces downtime and operational costs.

#### ***4.6.3.5 Outcome of the Theme Analysis 5***

The analysis of the Complaint Management Optimization theme reveals that the current complaint resolution process is hindered by delays caused by multiple hierarchical steps and a lack of access to historical maintenance data. The panels were unanimous in their support for reducing unnecessary approval steps to streamline the process, with many participants noting that this could save significant time in resolving complaints. By eliminating these bottlenecks, the complaint resolution process could become more agile, enabling the Public Works Department (PWD) to respond faster and more effectively to issues related to road electrical assets.

Additionally, the Historical Maintenance Access code emerged as a key element for improving the complaint management system. The ability to quickly access past maintenance records would allow for faster diagnosis of issues and enable more efficient handling of recurring problems. This integration would make the CMMS more effective in tracking and managing complaints, as it would provide real-time information on asset conditions and maintenance history.

This theme also highlights the need for a more efficient, integrated complaint management system that aligns with the overall goals of the CMMS. By reducing delays and improving access to critical data, the CMMS can support faster response times, ultimately improve service quality and reduce downtime for road electrical assets. The outcome of this analysis suggests that optimizing complaint management is a crucial step in enhancing the overall functionality of the CMMS.

#### **4.6.4 Conclusion & Outcomes for FGD**

This section has presented the results of the Atlas.ti analysis, focusing on the key themes that emerged from the focus group discussions (FGDs) regarding the potential integration of a Computerized Maintenance Management System (CMMS) for road electrical asset management. The analysis employed various methods such as Code Group Analysis, Code Document Analysis, Code Co-occurrence Analysis, and Thematic Analysis, has led to the identification of five central themes: System Integration Needs, CMMS Component Prioritization, Operational Challenges, Desired CMMS Features, and Complaint Management Optimization. Each of these themes reflects the panels' insights into the existing challenges and the essential features required to enhance maintenance practices through a CMMS solution.

## 4.7 Chapter Summary

This chapter summarizes with the review of maintenance documents revealed that while the Public Works Department (PWD) has an extensive set of records for road electrical assets, many of the data categories essential for a Computerized Maintenance Management System (CMMS) are incomplete or inconsistent. Critical information such as failure and incident reports, warranty details, and maintenance history is often fragmented or kept outside the REACT system. The mapping in Table 4.2 showed that most documents relate to asset condition and asset criticality, but there is far less coverage or implementation in categories that directly support preventive and predictive maintenance. This lack of features or practice limits the ability to centralize maintenance information and highlights the need for more comprehensive and accessible documentation before CMMS can be fully integrated.

The Monte Carlo simulation on the second research objective provided quantitative evidence of the potential benefits of CMMS adoption. By modelling historical 2023 complaint data for occurrence, frequency, and severity, the simulation compared the current process with one enhanced by CMMS. The results showed an average improvement of 11% in resolution time, with the duration falling from 22.92 days to 20.45 days. Gains were most significant during months with high complaint volumes and variability, suggesting that CMMS could stabilise performance by standardising workflows and ensuring more predictable response times. Even small process changes, such as removing one step from the complaint workflow, produced measurable efficiency gains.

The simulation also confirmed that many complaints currently take longer than the PWD Customer Charter's target resolution times, particularly for complex cases. Complaints that extend beyond 28 days were a major factor in the overall average, with manual form handling and multiple approval layers contributing to delays. Integrating complaint records with asset histories and maintenance schedules in a single CMMS platform would help reduce these delays and bring performance closer to service standards. This demonstrates the operational value of linking real-time failure data with proactive maintenance planning.

Lastly in the Focus Group Discussion (FGD) provided further insight into both the technical requirements and the practical challenges of CMMS implementation. Participants identified five key themes: system integration needs, CMMS component prioritisation, operational challenges, desired features, and complaint management optimisation. There was strong consensus on prioritising Maintenance Management first, followed by Asset Management and Inventory Control. Key features such as real-time data access, QR code asset tagging, battery lifespan monitoring, and vandalism alerts were highlighted as essential. At the same time, participants acknowledged constraints such as budget limitations, human resource shortages, and ageing infrastructure, pointing to the need for a phased implementation strategy.

Taken together, the findings from the document review, simulation, and FGD present a clear case for CMMS adoption to improve the efficiency, consistency, and responsiveness of road electrical asset management. Addressing documentation gaps will provide the data foundation needed for effective system integration, while the simulation demonstrates that even incremental process improvements can lead to meaningful time savings. The FGD findings offer a practical blueprint for prioritising features and managing implementation challenges. By acting on these combined insights, the PWD can move towards a unified, data-driven maintenance environment that reduces downtime, improves service delivery, and supports the long-term sustainability of critical infrastructure.

## **CHAPTER 5**

### **CONCLUSIONS**

#### **5.1 Introduction**

This chapter presented the conclusion of the study on the feasibility of integrating a Computerised Maintenance Management System (CMMS) into the Road Electrical Asset Control & Telemetry (REACT) system for managing road electrical assets such as traffic lights (TL) and street lighting (SL). The content was structured to summarise the key findings, evaluate the achievement of the research objectives, discuss the significance and contributions of the study, address its limitations, and provide recommendations for future work.

The main aim of this chapter was to bring together the evidence gathered from maintenance document reviews, simulation-based performance testing, and focus group discussions (FGD) with stakeholders. These elements had been analysed and compared with the findings from the literature review Chapter 2 to ensure the research results were grounded in both theoretical knowledge and practical relevance. This findings was written to be technically concise while also practical, providing a final perspective of the work undertaken.

#### **5.2 Summary of Key Findings**

The study produced a few important findings regarding the readiness, operational benefits, and implementation considerations of CMMS integration into REACT. These were drawn from three main data sources maintenance documents from the Public Works Department (PWD) Selangor, simulations to test process efficiency, and focus group discussions with engineers and technical staff that were focused on the methodology of study.

From the maintenance documents, it was observed that REACT already possesses essential potential features aligned with CMMS principles, including asset inventory, fault detection, and brand-agnostic integration. However, the documents also

revealed data gaps, particularly in historical repair logs and predictive asset lifespan analysis.

The simulation testing provided quantitative evidence of the benefits of CMMS integration. When CMMS functionalities such as automated work order generation and preventive scheduling were embedded into the REACT workflow or in this category of failure breakdown, the average time from fault detection to fault resolution was reduced by approximately 11%, from about 23 days to around 20.5 days. This result was significant because it translated directly into reduced downtime for critical road electrical assets, thereby improving service reliability and public safety.

Feedback from focus group discussions further confirmed the operational value of CMMS integration. Panels agreed that preventive maintenance is a necessity to enhanced, emergency repairs reduced, and data centralisation can be improved. However, they also raised concerns about the need for adequate staff training and process standardisation before full deployment. Major findings of this study was highlighted in table 5.1.

Table 5.1

Major findings of the Study

<b>Num</b>	<b>Item</b>	<b>Key Findings</b>	<b>Primary Source</b>
<b>1</b>	System Readiness	REACT includes core CMMS-compatible features (asset inventory, alerts, multi-brand integration). CMMS to be included	Maintenance documents RO1
<b>2</b>	Operational Impact	Fault resolution time reduced by over 11% in simulations after CMMS integration. Failure Breakdown or Work Order improvement	Simulation results RO2
<b>3</b>	Stakeholder Perception	Positive acceptance; agreement on maintenance management improvements.	Focus group discussions RO3
<b>4</b>	Data Gaps	Lack of complete historical repair logs and asset lifespan projections.	Maintenance documents RO2, FGDs RO3
<b>5</b>	Feasibility Factors	Technically feasible but requires training and process alignment. Strategic Implementation	All sources combined

The table shows that the REACT system already has several features that can work with a CMMS, such as asset inventory, alerts, and multi-brand integration, but it still needs improvements in data management and staff preparation. The simulation results demonstrated in clear operational benefits, with fault resolution time improving by over 11% after CMMS integration. Feedback from stakeholders supported the idea, highlighting better maintenance management while noting the need for training and standardised processes. Overall, the findings indicate that both the technical and organisational conditions are favourable for successful CMMS adoption.

### **5.3 Achievement on Research Objectives**

Each objective was examined considering the findings obtained from maintenance document analysis, simulation-based testing, and stakeholder feedback from focus group discussions. The aim was to verify whether the proposed CMMS integration model met the intended scope and addressed the practical needs of road electrical asset management within the PWD context. This study successfully achieved the three primary research objectives:

1. To determine the road electrical asset maintenance requirements: The study identified key gaps in the current maintenance practices, such as the lack of a structured preventive maintenance plan, historical maintenance and inconsistent breakdown records, limiting the effectiveness of the existing system.
2. To propose an ideal CMMS process tailored for road electrical assets: A CMMS model was proposed, a Swim Lane Model incorporating essential functions such as asset tagging, scheduling, inventory control, and data reporting. This model is designed for seamless integration with REACT and adaptable to various asset types and supplier brands. The simulation of study made only on Failure Breakdown or sub segment of CMMS.
3. To evaluate the feasibility of CMMS implementation at PWD: The feasibility was assessed using document-based simulations and qualitative data from focus group discussions. The results indicated that CMMS could

standardize maintenance processes, improve asset visibility, and reduce downtime, making it a valuable addition to the PWD's asset management strategy.

The three research objectives outlined in Chapter 1 were evaluated based on the evidence collected throughout the study.

Table 5.2

Research Objective Achievement & Evidence

<b>Research Objective</b>	<b>Achievement</b>	<b>Evidence</b>
RO1: Determine requirements of road electrical asset maintenance practices.	Core requirements identified: preventive and corrective maintenance schedules, real-time monitoring, systematic data capture.	Maintenance document analysis, literature review
RO2: Propose an ideal CMMS process tailored to road electrical assets.	Developed an integration model with asset database, automated work orders, preventive scheduling, and analytics dashboard. Failure Breakdown or Work Order Improvement	System mapping, Monte Carlo simulation Failure Records
RO3: Evaluate feasibility of CMMS implementation for PWD.	Feasibility confirmed with operational improvement and stakeholder support but requires data standardisation and training.	Simulation, FGDs

#### **5.4 Significance and Contributions of the Study**

This research makes significant contributions to both practical infrastructure management and academic research in many categories such as:

#### Practical Contributions:

The study proposes a CMMS framework that can be scaled and adapted by public agencies to improve the maintenance of road electrical assets such as traffic lights and street lighting. In the failure breakdown category, simulation results showed an 11% reduction in average resolution time from approximately 23 days to around 20.5 days after CMMS processes were applied. The integration model combines real-time fault detection from the REACT system with features such as digital inventory tracking, automated scheduling, and preventive maintenance alerts. This creates a more structured and proactive maintenance approach that could be implemented by PWD or replicated in other jurisdictions. The documented improvement in maintenance response time offers PWD a practical, evidence-based justification for future investment and budget planning.

#### Academic Contributions:

This work adds to the limited research on CMMS integration within road electrical infrastructure, particularly in Malaysia where such studies are rare. It demonstrates how a monitoring platform like REACT can be extended to support preventive maintenance and work order management, an area often treated separately in the literature. The findings also reinforce the role of data-driven decision-making in managing infrastructure more effectively, providing a practical example of how predictive maintenance principles can be applied in a real-world public sector environment.

#### Theoretical Significance:

The study extends existing CMMS literature by testing integration feasibility within a live IoT-based monitoring framework, tailored specifically to road electrical assets. The proposed hybrid model strengthens the connection between monitoring technologies and structured maintenance workflows, showing how these two traditionally separate domains can operate in a single unified platform. This addresses a notable gap in both local and international studies, especially in the Malaysian context where integration studies are scarce.

#### Policy and Operational Impact:

The results support the development of standardised maintenance protocols that could be applied across states, enabling more consistent and efficient public infrastructure management. By providing evidence of operational gains and stakeholder acceptance, the study offers policymakers a clearer pathway for scaling CMMS adoption beyond Selangor.

## **5.5 Limitations and Suggestion for Future Study**

While the findings of this study demonstrate the feasibility and potential benefits of CMMS integration into REACT, it is important to acknowledge the boundaries of its scope and the constraints encountered during the research. Recognising these limitations not only provides context for interpreting the results but also points towards avenues for further study.

While this study has provided valuable insights into the feasibility of integrating CMMS with the REACT system, several limitations should be acknowledged. First, the research was conducted solely within the context of PWD Selangor, focusing on traffic lights and street lighting as the primary asset categories. This already narrow down the scope, means the findings may not fully represent the challenges or operational realities faced by other states or for other types of road electrical assets, such as underground cables, CCTV networks, or flood monitoring sensors.

Secondly, the simulation testing was based on a controlled environment using selected assets in Selangor. While this allowed for more precise measurement of improvements in the failure breakdown category, it also limits the generalisability of the results to operate in different environments where asset diversity, traffic conditions, and resource allocation may vary significantly. Based on the proposed Swim Lane Model also, there are still many components in CMMS that can be tested.

Third, the stakeholder feedback was gathered exclusively from personnel within the Selangor context. Their perspectives may differ from those in other states where management practices, technical capabilities, and contractor relationships could present different implementation challenges. Even though it reflected the reality of the system implementation but there are still space for improvement.

Lastly, the study did not include a full cost-benefit analysis. This was primarily due to the unavailability of comprehensive financial data, such as actual maintenance costs, resource utilisation figures, and replacement budgets. As a result, the feasibility assessment was based largely on time efficiency metrics, which, while valuable, do not fully capture the economic implications of CMMS integration.

Building on these findings, there are several directions in which future research could expand. Future studies should expand the scope beyond PWD Selangor by including multiple states and additional electrical asset categories such as underground cables, CCTV networks, and flood monitoring sensors. This broader coverage would help validate whether the CMMS and REACT integration remains feasible across different operational environments.

Secondly, future research should conduct simulation testing using a wider range of assets and more varied operational conditions. In addition, other CMMS components that were not assessed in this study especially those related to operational workflows and maintenance planning should be tested to obtain a more complete evaluation of the system's capabilities.

Third, future studies should involve stakeholders from multiple states and agencies to capture different management practices, technical capabilities, and contractor ecosystems. This wider feedback base will provide a more representative assessment of organisational readiness and potential implementation challenges.

Finally, once detailed financial and operational data become available, future research should include a comprehensive cost-benefit analysis. This will allow a clearer understanding of the long-term economic impact of CMMS integration and provide stronger justification for budgeting and resource allocation.

The findings of this study also have important implications for policy. As CMMS integration grows, PWD and other government agencies may need to create standard guidelines for how digital maintenance systems should be used across different states. These guidelines could cover areas such as data management, system compatibility, user training, and contractor responsibilities.

If future studies involve more states and more types of assets, the results can help policymakers design a unified framework for maintenance management in Malaysia. This would ensure that REACT, CMMS, and other digital systems follow the same standards nationwide. Having clear policies in place will make CMMS implementation smoother, support long-term planning, and help strengthen Malaysia's overall digital transformation in public infrastructure.

Table 5.3

## Summary of Limitations and Future Research Directions

No.	Limitation	Future Research Recommendation
1	Scope limited to PWD Selangor's traffic lights and street lighting.	Expand scope to include underground cables, CCTV, flood sensors, and other electrical assets.
2	Simulation testing limited to selected assets in Selangor.	Conduct multi-state pilot programs for scalability and adaptability testing.
3	Stakeholder feedback gathered only from Selangor personnel.	Gather input from multiple states and agencies to identify regional differences.
4	No full cost-benefit analysis due to unavailable financial data.	Perform a detailed cost-benefit study when operational and financial data become available.
5	CMMS components not fully tested, especially predictive functions.	Explore AI-driven predictive analytics for enhanced maintenance planning.

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## **APPENDICES**

# APPENDIX I

## Letter of Research Intention at PWD of Selangor

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UNIVERSITI  
TEKNOLOGI  
MARA

Institut  
Pengkangkutan  
Malaysia

Surat Kami : 6Q0-MITRANS (5/2)  
Tarikh : 1445H „V^24  
05 Mac 2024

Ir. HAMIFF BIN AB HAMID  
Ketua Jurutera Elektrik Negeri Selangor  
Pejabat Cawangan Kejuruteraan Elektrik  
Tingkat 3, Kompleks Iba Pejabat JKR Selangor  
Persiaran Jubli Perak. Seksyen 17  
40200 Sbah Alam. Selangor

JJSA jjijiliu \*i£? tu^ dan Salam Sejahtera

Tuan

PERMOHONAN MELAKSANAKAN KAJIAN BERKENAAN DEMGAN SISTEM ROAD ELECTRICAL ASSET CONTROL & TELEMETRY (REACT) CAWANGAN KEJURUTERAAN ELEKTRIK, JKR NEGERI SELANGOR

Dengan segala hormatnya perkara tersebut di atas adalah dirujuk.

2. Untuk makluman tuan, pelajar kami Amar Amjad bin Abdul Wahid (No pelajar: 2023656924) merupakan pelajar Sarjana Sains Pengangkutan Logistik di Institut Pengangkutan Malaysia (MITRANS) UiTM Sbah Alam sedang menjalankan kajian berkenaan penambahbaikan sistem REACT yang digunakan di pejabat tuan.

3. Kajian ini bertujuan untuk melihat kebolehlaksanaan sistem REACT dalam mengadaptasi sistem pengurusan penyenggaraan berkomputer atau *Computerised Maintenance Management System (CMMS)*. Selain itu, kajian ini juga dapat memberikan ulasan akademik bagi menambah nilai dalam teknologi dan inovasi sistem yang digunakan.

4. Sehubungan dengan itu, kami dengan ini ingin memohon kebenaran untuk melaksanakan kajian dan mengakses maklumat yang berpatutan bagi menjayakan kajian tersebut. Adalah diharapkan, hasil kajian tersebut boleh dimanfaatkan oleh organisasi tuan sebagai sebuah badan profesional yang inovatif dan kreatif di persada antarabangsa serta menambah mutu kualiti sistem sedia ada.

4. Segala usahasama yang diberikan oleh pejabat tuan adalah amat dihargai dan sentiasa didahulukan dengan ucapan terima kasih.

Sekian. Wassalam

"MALAYSIA MADANI"  
"BERKHIDMAT UNTUK NEGARA"

Saya yang menjalankan amanah.

PROF. MADYA TS. DR. S SARIFAH RADIAH SHARIFF  
Timbalan Pengarah (Penyelidikan dan Pendidikan)

Universiti Teknologi MARA  
1(6450) Shah Alam, Selangor, MALAYSIA  
Tel: (+603) 5544 2350/2352/2345/2343  
Faks: (+603) 5544 2344  
H-mel: [uitm@uitm.edu.my](mailto:uitm@uitm.edu.my), [L@J.JHV](mailto:uitm@uitm.edu.my)  
[www.mil.tms.uitm.edu.my](http://www.mil.tms.uitm.edu.my)

**IRAH**  
UITMHSBS

## **APPENDIX II**

### **Replied Letter of Research Intention at PWD of Selangor**

## APPENDIX III

### Data Elements of REACT and Maintenance Information (System Owner)

Data Category	Data Elements	Importance for Maintenance	Implemented / Practiced (System Owner)
<b>Asset Identification</b>	Asset name or description	Helps in quick asset identification during maintenance.	Yes
	Unique asset identifier or serial number	Ensures precise tracking of individual assets.	Yes
	Asset location (geographical or within a facility)	Enables maintenance teams to locate assets efficiently.	Yes
	Asset category or type (e.g., equipment, machinery, vehicles)	Aids in organizing maintenance tasks by asset type.	Yes
<b>Asset Specifications</b>	Technical specifications and details	Provides insights into asset capabilities and requirements.	Yes
	Manufacturer information	Helps in sourcing parts and expertise for repairs.	No
	Installation date	Determines the asset's age and potential maintenance needs.	Yes
	Expected service life	Indicates when major overhauls or replacements may be required.	No
<b>Maintenance History</b>	Records of past maintenance and repairs	Offers insights into recurring issues and preventive measures.	No
	Maintenance schedules and plans	Guides future maintenance and inspections.	No
<b>Warranty and Documentation</b>	Warranty information	Ensures compliance with warranty terms and conditions.	No
	Manuals and documentation related to the asset	Assists in proper maintenance and troubleshooting.	No
<b>Asset Condition</b>	Current condition or status of the asset (New or Spare)	Provides a snapshot of immediate maintenance requirements.	Yes

	Inspection reports	Records observations for potential corrective actions.	No
<b>Asset Criticality</b>	Importance or criticality of the Asset to operations (minimum lifespan estimation)	Guides prioritization of maintenance efforts.	No
<b>Spare Parts and Inventory</b>	List of spare parts and associated inventory	Facilitates quick part replacement during maintenance.	No
	Ordering and restocking details	Maintains efficient inventory management for minimal downtime.	No
<b>Maintenance Tasks</b>	List of routine maintenance tasks required	Forms the basis for maintenance planning and schedules.	No
	Frequency and procedures for maintenance	Guides technicians in performing maintenance tasks correctly.	No
<b>Maintenance Contacts</b>	Personnel responsible for asset maintenance	Ensures accountability and easy contact for maintenance teams.	No
	Contact information for maintenance providers	Facilitates external service provider coordination.	No
<b>Failure and Incident Reports</b>	Records of asset failures, breakdowns, or incidents	Offers insights into asset weaknesses and areas for improvement.	No

## APPENDIX IV

### Data Elements of REACT and Maintenance Information (System Integrator)

<b>Data Category</b>	<b>Data Elements</b>	<b>Importance for Maintenance</b>	<b>Implemented / Practiced (System Integrator)</b>
<b>Asset Identification</b>	Asset name or description	Helps in quick asset identification during maintenance.	Yes
	Unique asset identifier or serial number	Ensures precise tracking of individual assets.	Yes
	Asset location (geographical or within a facility)	Enables maintenance teams to locate assets efficiently.	Yes
	Asset category or type (e.g., equipment, machinery, vehicles)	Aids in organizing maintenance tasks by asset type.	Yes
<b>Asset Specifications</b>	Technical specifications and details	Provides insights into asset capabilities and requirements.	Yes
	Manufacturer information	Helps in sourcing parts and expertise for repairs.	Yes
	Installation date	Determines the asset's age and potential maintenance needs.	Yes
	Expected service life	Indicates when major overhauls or replacements may be required.	No
<b>Maintenance History</b>	Records of past maintenance and repairs	Offers insights into recurring issues and preventive measures.	No
	Maintenance schedules and plans	Guides future maintenance and inspections.	No
<b>Warranty and Documentation</b>	Warranty information	Ensures compliance with warranty terms and conditions.	No
	Manuals and documentation related to the asset	Assists in proper maintenance and troubleshooting.	No

<b>Asset Condition</b>	Current condition or status of the asset (New or Spare)	Provides a snapshot of immediate maintenance requirements.	Yes
	Inspection reports	Records observations for potential corrective actions.	No
<b>Asset Criticality</b>	Importance or criticality of the Asset to operations (minimum lifespan estimation)	Guides prioritization of maintenance efforts.	No
<b>Spare Parts and Inventory</b>	List of spare parts and associated inventory	Facilitates quick part replacement during maintenance.	No
	Ordering and restocking details	Maintains efficient inventory management for minimal downtime.	No
<b>Maintenance Tasks</b>	List of routine maintenance tasks required	Forms the basis for maintenance planning and schedules.	No
	Frequency and procedures for maintenance	Guides technicians in performing maintenance tasks correctly.	No
<b>Maintenance Contacts</b>	Personnel responsible for asset maintenance	Ensures accountability and easy contact for maintenance teams.	Yes
	Contact information for maintenance providers	Facilitates external service provider coordination.	No
<b>Failure and Incident Reports</b>	Records of asset failures, breakdowns, or incidents	Offers insights into asset weaknesses and areas for improvement.	No

## APPENDIX V

### List of Documents Reviewed

<b>Num.</b>	<b>Document</b>
1	User Manual REACT JKR Selangor
2	Memorandum of Understanding REACT
3	Template Inventori Lampu Jalan
4	Template Inventori Lampu Isyarat
5	Piagam Pelanggan JKR Malaysia
6	JKR.PK(P).11-1 K7P2 Borang Aduan
7	JKR.PK(P).11-2 K7P2 Borang 2
8	JKR.PK(P).11-3 K7P2 Lampiran 3
9	JKR.PK(P).11-4 K7P2 Lampiran 4
10	JKR.PK(P).11-5 K7P2 Lampiran 5
11	APJ Geran Padanan Contoh
12	MySPATA D.A.(E)
13	SISPAA
14	Checklist for Visual Inspection of Low Voltage Electrical Boards
15	Warranty Declaration Form
16	Factory Acceptance Test Report (Street Lighting)
17	Factory Acceptance Test Report (Traffic Light)
18	Monthly Report on Damage Complaints and Electrical Services
19	On-Site Asset Damage Report
20	Maintenance Work Report
21	Spare Parts Inventory List

## APPENDIX V1

### Number of Complaint in the Year 2023

Number of Failure Records in Days of Months												
Days	January	February	March	April	May	June	July	August	September	October	November	December
1	0	1	5	0	0	1	0	1	5	0	3	0
2	0	1	2	0	9	2	0	3	0	2	5	0
3	2	6	0	5	3	0	1	1	0	4	1	0
4	3	0	0	5	0	0	1	3	3	2	0	6
5	1	0	0	2	2	0	2	0	3	0	0	3
6	1	0	2	1	0	1	3	0	1	4	7	2
7	0	4	3	1	0	1	2	6	1	0	2	0
8	0	8	2	0	4	1	0	1	3	0	3	0
9	3	4	0	0	3	3	0	3	0	5	2	0
10	4	8	9	3	2	0	0	3	0	0	9	0
11	6	0	0	5	1	0	2	5	5	3	0	1
12	2	0	0	0	4	0	3	0	2	4	0	4
13	2	5	6	3	0	0	0	0	6	5	0	3
14	0	4	2	0	0	2	1	0	7	0	2	1
15	0	3	1	0	0	0	0	2	5	0	3	2
16	3	3	2	0	3	4	0	8	0	4	3	0
Cont.												
17	4	4	4	2	1	0	4	1	0	5	0	0

18	1	0	0	2	4	0	1	3	2	2	0	5
19	1	0	0	0	0	2	0	0	3	3	0	3
20	2	1	4	0	0	1	2	0	9	1	2	6
21	0	1	3	0	0	3	4	7	0	0	5	5
22	0	4	3	0	6	1	0	6	3	0	2	2
23	0	4	4	0	0	0	0	4	0	3	1	0
24	0	5	1	0	1	0	2	3	0	6	4	0
25	0	0	0	3	0	0	1	3	4	5	0	0
26	7	2	0	0	1	3	2	0	2	3	0	4
27	0	1	4	1	0	0	1	0	2	1	5	1
28	3	0	2	0	0	0	5	5	0	0	4	6
29	0		2	0	2	0	0	2	1	0	4	1
30	8		5	0	1	0	0	1	0	4	0	0
31	3		2		2		5	0		2		0
<b>Sum</b>	<b>56</b>	<b>69</b>	<b>68</b>	<b>33</b>	<b>49</b>	<b>25</b>	<b>42</b>	<b>71</b>	<b>67</b>	<b>68</b>	<b>67</b>	<b>55</b>
<b>2023 Failure Registry</b>												<b>670</b>
<b>Average Failure Registry Per Month</b>											<b>55.83</b>	<b>56 Days</b>

## APPENDIX VII

### Number of Complaint in the Year 2023 by Days

NUM	MONTH	YEAR	NUMBER OF COMPLAINTS ELECTRICAL COMPONENT RELATED	DAYS COMPLAINTS REPLIED TO CUSTOMER (SOLVED)								
				0 Day	>1 Days	>7 Days	>14 Days	>21 Days	>28 Days	>60 Days	>90 Days	>120 Days
1	JANUARY	2023	56	6	23	9	6	6	6	0	0	0
2	FEBRUARY	2023	69	3	23	25	12	4	2	0	0	0
3	MARCH	2023	68	6	23	18	12	5	4	0	0	0
4	APRIL	2023	33	3	12	6	4	3	5	0	0	0
5	MAY	2023	49	6	31	9	1	0	2	0	0	0
6	JUNE	2023	25	3	8	4	5	0	5	0	0	0
7	JULY	2023	42	2	5	8	2	3	<b>22</b>	0	0	0
8	AUGUST	2023	71	5	23	18	7	9	9	0	0	0
9	SEPTEMBER	2023	67	5	29	6	4	4	19	0	0	0
10	OCTOBER	2023	68	6	16	19	5	0	<b>22</b>	0	0	0
11	NOVEMBER	2023	67	9	4	7	0	0	35	10	2	0
12	DECEMBER	2023	55	4	11	1	1	0	32	4	2	0
Total Number of Complaints			670									
Total Number of Complaints Replied to Customer				58	208	130	59	34	163	14	4	0

## APPENDIX VIII

### Summary of Severity Distribution

Distribution of Days	Level 1	Level 2	Level 3	Level 4	Level 5	Sum
0 to 1	16	1	18	14	9	58
2 to 6	21	23	103	50	11	208
7 to 13	6	13	86	20	5	130
14 to 20	1	4	32	14	8	59
21 to 27	4	2	19	6	3	34
28 to 59	6	12	103	29	13	163
60 to 90	0	1	12	1	0	14
90 to 120	0	0	4	0	0	4
Sum	54	56	377	134	49	670

## APPENDIX IX

### Severity Distribution Table by Levels

#### Severity Level 1: Insignificant

Distribution of Days	Mid values	Frequency	Total Number of Days	Probability	Cummulative Probability
0 to 1	0.5	16	8.0	30%	30%
2 to 6	4	21	84.0	39%	69%
7 to 13	10	6	60.0	11%	80%
14 to 20	17	1	17.0	2%	81%
21 to 27	24	4	96.0	7%	89%
28 to 59	57.5	6	345.0	11%	100%
60 to 90	75	0	0.0	0%	-
90 to 120	105	0	0.0	0%	-
Total number of days		54	610.0	100%	
Average Number of Days			11.3		
Average Number of Days for a Complaint to Solve			12.0		

**Severity Level 2: Minor**

Distribution of Days	Mid values	Frequency	Total Number of Days	Probability	Cummulative Probability
0 to 1	0.5	1	0.5	2%	2%
2 to 6	4	23	92.0	41%	43%
7 to 13	10	13	130.0	23%	66%
14 to 20	17	4	68.0	7%	73%
21 to 27	24	2	48.0	4%	77%
28 to 59	57.5	12	690.0	21%	98%
60 to 90	75	1	75.0	2%	100%
90 to 120	105	0	0.0	0%	-
Total number of days		56	1103.5	100%	
Average Number of Days			19.7		
Average Number of Days for a Complaint to Solve			20.0		

**Severity Level 3: Moderate**

Distribution of Days	Mid values	Frequency	Total Number of Days	Probability	Cummulative Probability
0 to 1	0.5	18	9.0	5%	5%
2 to 6	4	103	412.0	27%	32%
7 to 13	10	86	860.0	23%	55%
14 to 20	17	32	544.0	8%	63%
21 to 27	24	19	456.0	5%	68%
28 to 59	57.5	103	5922.5	27%	96%
60 to 90	75	12	900.0	3%	99%
90 to 120	105	4	420.0	1%	100%
Total number of days		377	9523.5	100%	

Average Number of Days	25.3		
Average Number of Days for a Complaint to Solve	26.0		

**Severity Level 4: Major**

Distribution of Days	Mid values	Frequency	Total Number of Days	Probability	Cummulative Probability
0 to 1	0.5	14	7.0	10%	10%
2 to 6	4	50	200.0	37%	48%
7 to 13	10	20	200.0	15%	63%
14 to 20	17	14	238.0	10%	73%
21 to 27	24	6	144.0	4%	78%
28 to 59	57.5	29	1667.5	22%	99%
60 to 90	75	1	75.0	1%	100%
90 to 120	105	0	0.0	0%	
Total number of days		134	2531.5	100%	
Average Number of Days			18.9		
Average Number of Days for a Complaint to Solve			19.0		

**Severity Level 5: Critical**

Distribution of Days	Mid values	Frequency	Total Number of Days	Probability	Cummulative Probability
0 to 1	0.5	9	4.5	18%	18%
2 to 6	4	11	44.0	22%	41%
7 to 13	10	5	50.0	10%	51%
14 to 20	17	8	136.0	16%	67%
21 to 27	24	3	72.0	6%	73%
28 to 59	57.5	13	747.5	27%	100%
60 to 90	75	0	0.0	0%	-
90 to 120	105	0	0.0	0%	-
Total number of days		49	1054.0	100%	
Average Number of Days			21.5		
Average Number of Days for a Complaint to Solve			22.0		

## APPENDIX X

### Monte Carlo Simulation Iteration Tables for Year 2023

JANUARY 2023 ITERATION TABLE

Number Iteration	Average Number of Complaint per Day	Standard Deviation	Average Severity Type 1	Average Severity Type 2	Average Severity Type 3	Average Severity Type 4	Average Severity Type 5	Average of Days Complaint to Solve Before CMMS	Average of Days Complaint to Solve with CMMS
1	1.74	2.28	8	3	14	19	0	21.00	18.00
2	1.39	1.61	6	1	14	18	0	21.00	18.00
3	2.25	2.24	11	5	29	42	0	21.00	19.00
4	0.87	1.45	3	1	7	8	0	21.00	19.00
5	1.03	1.58	4	0	8	14	0	21.00	18.00
6	1.16	1.59	5	1	7	16	0	20.00	18.00
7	1.32	1.97	4	3	14	13	0	22.00	19.00
8	1.61	2.32	6	1	19	19	0	22.00	19.00
9	1.58	2.13	9	2	11	19	0	20.00	17.00
10	1.52	2.14	5	0	12	24	0	21.00	18.00
<b>Average</b>	1.45	1.93	6.1	1.7	13.5	19.2	0	21	18
<b>Improvement Percentage (%)</b>									13%

FEBRUARY 2023 ITERATION TABLE

Number Iteration	Average Number of Complaint per Day	Standard Deviation	Average Severity Type 1	Average Severity Type 2	Average Severity Type 3	Average Severity Type 4	Average Severity Type 5	Average of Days Complaint to Solve Before CMMS	Average of Days Complaint to Solve with CMMS
1	1.96	2.28	1	2	43	15	4	24.00	22.00
2	1.96	2.71	3	2	41	16	3	24.00	21.00
3	1.29	2.11	2	1	20	11	2	23.00	21.00
4	2.29	2.93	1	5	39	13	6	24.00	22.00
5	0.81	1.44	0	0	24	8	2	25.00	22.00
6	1.67	2.27	1	1	39	12	4	24.00	22.00
7	1.14	1.99	1	0	22	9	0	24.00	22.00
8	2.25	2.30	0	2	37	18	6	24.00	21.00
9	1.75	2.74	1	3	31	13	1	24.00	21.00
10	1.68	2.31	0	1	27	19	0	24.00	21.00
<b>Average</b>	1.68	2.31	1	1.7	32.3	13.4	2.8	24	21.5
<b>Improvement Percentage (%)</b>									10%

MARCH 2023 ITERATION TABLE

Number Iteration	Average Number of Complaint per Day	Standard Deviation	Average Severity Type 1	Average Severity Type 2	Average Severity Type 3	Average Severity Type 4	Average Severity Type 5	Average of Days Complaint to Solve Before CMMS	Average of Days Complaint to Solve with CMMS
1	1.52	2.29	1	2	22	13	9	23.00	21.00
2	1.87	2.39	6	1	28	14	9	23.00	20.00
3	1.45	1.79	2	2	25	11	5	23.00	21.00
4	1.94	2.25	5	4	36	10	5	23.00	21.00
5	1.26	1.88	2	2	25	3	7	24.00	22.00
6	1.55	1.84	6	4	27	6	5	23.00	20.00
7	1.61	2.03	3	3	26	8	10	23.00	21.00
8	1.32	1.89	7	1	18	3	12	22.00	20.00
9	1.42	2.09	5	2	27	4	6	23.00	21.00
10	1.65	2.35	8	2	20	10	11	22.00	19.00
<b>Average</b>	1.56	2.08	4.5	2.3	25.4	8.2	7.9	22.9	20.6
<b>Improvement Percentage (%)</b>									10%

APRIL 2023 ITERATION TABLE

Number Iteration	Average Number of Complaint per Day	Standard Deviation	Average Severity Type 1	Average Severity Type 2	Average Severity Type 3	Average Severity Type 4	Average Severity Type 5	Average of Days Complaint to Solve Before CMMS	Average of Days Complaint to Solve with CMMS
1	0.40	1.10	1	1	4	3	3	22.00	20.00
2	0.50	1.36	2	2	4	6	1	21.00	18.00
3	0.40	1.10	0	3	4	5	0	22.00	20.00
4	0.60	1.43	3	3	6	6	0	21.00	18.00
5	0.73	1.51	1	2	14	5	0	24.00	21.00
6	0.27	1.05	0	2	2	4	0	21.00	19.00
7	0.33	1.09	0	0	3	7	0	22.00	19.00
8	0.70	1.42	3	3	8	5	2	22.00	19.00
9	0.60	1.28	1	4	8	4	1	23.00	20.00
10	0.73	1.46	1	0	10	9	2	23.00	20.00
<b>Average</b>	0.53	1.28	1.2	2	6.3	5.4	0.9	22.1	19.4
<b>Improvement Percentage (%)</b>									12%

MAY 2023 ITERATION TABLE

Number Iteration	Average Number of Complaint per Day	Standard Deviation	Average Severity Type 1	Average Severity Type 2	Average Severity Type 3	Average Severity Type 4	Average Severity Type 5	Average of Days Complaint to Solve Before CMMS	Average of Days Complaint to Solve with CMMS
1	0.63	1.85	6	3	12	8	2	21.00	19.00
2	0.87	1.12	4	2	14	7	0	22.00	20.00
3	0.84	2.27	1	6	9	10	0	22.00	19.00
4	0.52	1.39	1	7	5	3	0	22.00	19.00
5	0.55	1.18	3	2	10	2	0	22.00	20.00
6	0.97	1.70	1	5	15	7	2	23.00	21.00
7	0.81	1.14	2	2	12	7	2	23.00	20.00
8	1.35	1.96	1	12	17	11	1	23.00	20.00
9	0.74	1.55	1	4	10	8	0	22.00	20.00
10	0.97	2.22	2	4	18	17	0	22.00	20.00
<b>Average</b>	0.82	1.64	2.2	4.7	12.2	8	0.7	22.2	19.8
<b>Improvement Percentage (%)</b>									11%

JUNE 2023 ITERATION TABLE

Number Iteration	Average Number of Complaint per Day	Standard Deviation	Average Severity Type 1	Average Severity Type 2	Average Severity Type 3	Average Severity Type 4	Average Severity Type 5	Average of Days Complaint to Solve Before CMMS	Average of Days Complaint to Solve with CMMS
1	0.37	0.81	3	2	3	2	1	20.00	17.00
2	0.27	0.69	0	1	7	0	0	26.00	23.00
3	0.45	0.87	2	4	13	5	1	23.00	20.00
4	0.13	0.73	0	1	2	0	1	24.00	22.00
5	0.10	0.31	1	1	1	0	0	20.00	17.00
6	0.17	0.65	0	1	1	3	0	21.00	19.00
7	0.33	0.66	1	3	3	2	1	21.00	19.00
8	0.27	0.69	2	2	4	0	0	21.00	19.00
9	0.53	0.82	2	3	10	1	0	23.00	21.00
10	0.27	0.78	1	2	3	2	0	21.00	19.00
<b>Average</b>	0.29	0.70	1.2	2	4.7	1.5	0.4	22	19.6
<b>Improvement Percentage (%)</b>									11%

JULY 2023 ITERATION TABLE

Number Iteration	Average Number of Complaint per Day	Standard Deviation	Average Severity Type 1	Average Severity Type 2	Average Severity Type 3	Average Severity Type 4	Average Severity Type 5	Average of Days Complaint to Solve Before CMMS	Average of Days Complaint to Solve with CMMS
1	0.32	0.94	1	1	7	1	0	24.00	21.00
2	0.81	1.22	3	3	16	2	1	23.00	21.00
3	0.84	1.32	2	5	13	5	1	23.00	20.00
4	0.81	1.22	1	5	17	2	0	24.00	22.00
5	0.48	0.93	1	1	8	4	1	23.00	21.00
6	0.26	0.96	0	0	7	1	0	26.00	23.00
7	1.00	1.41	0	4	21	6	0	24.00	22.00
8	0.65	0.98	1	4	12	3	0	24.00	21.00
9	0.35	1.25	0	0	8	3	0	25.00	22.00
10	0.77	1.33	2	4	13	4	1	23.00	21.00
<b>Average</b>	0.63	1.16	1.1	2.7	12.2	3.1	0.4	23.9	21.4
<b>Improvement Percentage (%)</b>									10%

AUGUST 2023 ITERATION TABLE

Number Iteration	Average Number of Complaint per Day	Standard Deviation	Average Severity Type 1	Average Severity Type 2	Average Severity Type 3	Average Severity Type 4	Average Severity Type 5	Average of Days Complaint to Solve Before CMMS	Average of Days Complaint to Solve with CMMS
1	1.94	2.21	4	2	42	9	3	24.00	22.00
2	1.74	2.32	2	5	32	9	6	24.00	21.00
3	1.29	1.97	3	0	30	1	6	25.00	22.00
4	1.81	2.41	3	4	39	7	3	24.00	22.00
5	1.13	1.73	2	1	26	5	1	24.00	22.00
6	1.45	2.11	2	3	30	7	3	24.00	22.00
7	1.90	2.20	3	6	38	9	3	24.00	21.00
8	1.74	2.05	2	1	36	12	3	24.00	22.00
9	1.33	2.15	1	4	31	12	4	24.00	21.00
10	1.32	1.94	3	1	27	7	3	24.00	21.00
<b>Average</b>	1.57	2.11	2.5	2.7	33.1	7.8	3.5	24.1	21.6
<b>Improvement Percentage (%)</b>									10%

SEPTEMBER 2023 ITERATION TABLE

Number Iteration	Average Number of Complaint per Day	Standard Deviation	Average Severity Type 1	Average Severity Type 2	Average Severity Type 3	Average Severity Type 4	Average Severity Type 5	Average of Days Complaint to Solve Before CMMS	Average of Days Complaint to Solve with CMMS
1	0.83	1.34	4	2	24	6	0	23.00	21.00
2	2.17	2.97	11	5	35	14	0	22.00	20.00
3	0.97	1.71	4	3	19	3	0	23.00	21.00
4	0.90	1.65	4	2	18	3	0	23.00	21.00
5	1.47	2.05	5	2	31	6	0	24.00	21.00
6	1.17	1.60	4	0	24	7	0	23.00	21.00
7	0.53	1.41	3	0	8	5	0	22.00	19.00
8	1.93	2.39	5	5	39	9	0	24.00	21.00
9	1.03	1.54	1	2	24	4	0	25.00	22.00
10	0.90	1.35	3	2	18	4	0	23.00	21.00
<b>Average</b>	1.19	1.80	4.4	2.3	24	6.1	0	23.2	20.8
<b>Improvement Percentage (%)</b>									10%

OCTOBER 2023 ITERATION TABLE

Number Iteration	Average Number of Complaint per Day	Standard Deviation	Average Severity Type 1	Average Severity Type 2	Average Severity Type 3	Average Severity Type 4	Average Severity Type 5	Average of Days Complaint to Solve Before CMMS	Average of Days Complaint to Solve with CMMS
1	1.39	1.80	2	3	22	10	6	23.00	21.00
2	1.45	1.80	6	4	17	13	5	22.00	19.00
3	1.87	1.94	5	9	22	17	5	22.00	19.00
4	1.42	1.84	3	6	16	14	5	22.00	20.00
5	1.00	1.46	7	0	16	5	3	22.00	19.00
6	1.23	1.85	3	4	30	9	3	24.00	21.00
7	1.29	1.87	5	4	20	9	2	22.00	20.00
8	2.13	2.25	6	7	31	18	4	22.00	20.00
9	1.63	1.92	6	8	34	12	1	23.00	20.00
10	1.71	1.85	4	7	25	13	4	23.00	20.00
<b>Average</b>	1.51	1.86	4.7	5.2	23.3	12	3.8	22.5	19.9
<b>Improvement Percentage (%)</b>									12%

NOVEMBER 2023 ITERATION TABLE

Number Iteration	Average Number of Complaint per Day	Standard Deviation	Average Severity Type 1	Average Severity Type 2	Average Severity Type 3	Average Severity Type 4	Average Severity Type 5	Average of Days Complaint to Solve Before CMMS	Average of Days Complaint to Solve with CMMS
1	0.90	1.56	3	2	18	3	1	24.00	21.00
2	1.30	2.31	3	4	28	4	0	24.00	22.00
3	0.90	1.40	1	4	18	4	0	24.00	22.00
4	0.63	1.30	1	0	16	2	0	25.00	23.00
5	1.55	1.68	4	6	39	7	1	24.00	21.00
6	1.60	1.96	4	5	34	5	0	24.00	21.00
7	1.13	1.59	0	4	27	2	1	25.00	23.00
8	1.83	2.42	4	6	39	6	0	24.00	22.00
9	1.37	1.81	1	5	34	1	0	25.00	23.00
10	1.40	2.16	3	3	31	4	1	24.00	22.00
<b>Average</b>	1.26	1.82	2.4	3.9	28.4	3.8	0.4	24.3	22
<b>Improvement Percentage (%)</b>									9%

DECEMBER 2023 ITERATION TABLE

Number Iteration	Average Number of Complaint per Day	Standard Deviation	Average Severity Type 1	Average Severity Type 2	Average Severity Type 3	Average Severity Type 4	Average Severity Type 5	Average of Days Complaint to Solve Before CMMS	Average of Days Complaint to Solve with CMMS
1	1.16	1.83	2	5	22	5	2	24.00	21.00
2	0.71	1.72	5	1	13	3	0	22.00	20.00
3	1.23	2.03	10	3	19	6	0	21.00	19.00
4	1.45	2.17	6	4	31	3	1	24.00	21.00
5	0.81	1.66	3	0	20	0	2	24.00	22.00
6	0.60	1.40	6	3	16	2	3	22.00	20.00
7	0.87	1.71	4	1	18	4	0	23.00	21.00
8	1.00	1.79	7	3	18	3	0	22.00	20.00
9	1.45	2.28	9	5	27	3	1	22.00	20.00
10	0.57	1.41	3	2	20	3	1	24.00	21.00
<b>Average</b>	0.98	1.80	5.5	2.7	20.4	3.2	1	22.8	20.5
<b>Improvement Percentage (%)</b>									10%

5.6

## APPENDIX XI

### Daily Distribution Occurrence (Yes/No)

Date: <b>January</b>	Number of Complaints occurrence	Probability	Cumulative Probability	Random Number (2 Digit)	Yes / No	Logic
1	0	0%	0%	00-00	No	0
2	0	0%	0%	00-00	No	0
3	2	4%	4%	01-04	Yes	1
4	3	5%	9%	05-09	Yes	1
5	1	2%	11%	10-11	Yes	1
6	1	2%	13%	12-13	Yes	1
7	0	0%	13%	14-15	No	0
8	0	0%	13%	16-17	No	0
9	3	5%	18%	18-19	Yes	1
10	4	7%	25%	20-25	Yes	1
11	6	11%	36%	26-36	Yes	1
12	2	4%	39%	37-39	Yes	1
13	2	4%	43%	40-43	Yes	1
14	0	0%	43%	44-45	No	0
15	0	0%	43%	46-47	No	0
16	3	5%	48%	48-49	Yes	1
17	4	7%	55%	50-55	Yes	1
18	1	2%	57%	56-57	Yes	1
19	1	2%	59%	58-59	Yes	1
20	2	4%	63%	60-63	Yes	1
21	0	0%	63%	64-65	No	0
22	0	0%	63%	66-67	No	0
23	0	0%	63%	68-69	No	0
24	0	0%	63%	70-71	No	0
25	0	0%	63%	72-73	No	0
26	7	13%	75%	74-75	Yes	1
27	0	0%	75%	76-77	No	0
28	3	5%	80%	78-80	Yes	1
29	0	0%	80%	81-82	No	0
30	8	14%	95%	83-95	Yes	1
31	3	5%	100%	96-99	Yes	1
<b>Sum</b>	<b>56</b>				18	13

Month: <b>February</b>	Number of Complaints occurrence	Probability	Cumulative Probability	Random Number (2 Digit)	Yes / No	Logic
1	1	1%	1%	00-03	Yes	1
2	1	1%	3%	04-06	Yes	1
3	6	9%	12%	07-10	Yes	1
4	0	0%	12%	11-14	No	0
5	0	0%	12%	15-17	No	0
6	0	0%	12%	18-20	No	0
7	4	6%	17%	21-24	Yes	1
8	8	12%	29%	25-28	Yes	1
9	4	6%	35%	29-32	Yes	1
10	8	12%	46%	33-36	Yes	1
11	0	0%	46%	37-39	No	0
12	0	0%	46%	40-42	No	0
13	5	7%	54%	43-45	Yes	1
14	4	6%	59%	46-48	Yes	1
15	3	4%	64%	49-51	Yes	1
16	3	4%	68%	52-54	Yes	1
17	4	6%	74%	55-57	Yes	1
18	0	0%	74%	58-60	No	0
19	0	0%	74%	61-63	No	0
20	1	1%	75%	64-66	Yes	1
21	1	1%	77%	67-69	Yes	1
22	4	6%	83%	70-72	Yes	1
23	4	6%	88%	73-76	Yes	1
24	5	7%	96%	77-80	Yes	1
25	0	0%	96%	81-85	No	0
26	2	3%	99%	86-89	Yes	1
27	1	1%	100%	90-94	Yes	1
28	0	0%	100%	95-99	No	0
29						
30						
31						
<b>Sum</b>	<b>69</b>				19	9
Month: <b>March</b>	Number of Complaints Occurrence	Probability	Cumulative Probability	Random Number (2 Digit)	Yes / No	Logic
1	5	7%	7%	00-03	Yes	1
2	2	3%	10%	04-06	Yes	1

3	0	0%	10%	07-09	No	0
4	0	0%	10%	10-12	No	0
5	0	0%	10%	13-15	No	0
6	2	3%	13%	16-18	Yes	1
7	3	4%	18%	19-21	Yes	1
8	2	3%	21%	22-24	Yes	1
9	0	0%	21%	25-27	No	0
10	9	13%	34%	28-30	Yes	1
11	0	0%	34%	31-33	No	0
12	0	0%	34%	34-36	No	0
13	6	9%	43%	37-39	Yes	1
14	2	3%	46%	40-42	Yes	1
15	1	1%	47%	43-45	Yes	1
16	2	3%	50%	46-48	Yes	1
17	4	6%	56%	49-51	Yes	1
18	0	0%	56%	52-54	No	0
19	0	0%	56%	55-57	No	0
20	4	6%	62%	58-60	Yes	1
21	3	4%	66%	61-63	Yes	1
22	3	4%	71%	64-66	Yes	1
23	4	6%	76%	67-69	Yes	1
24	1	1%	78%	70-72	Yes	1
25	0	0%	78%	73-75	No	0
26	0	0%	78%	76-78	No	0
27	4	6%	84%	79-81	Yes	1
28	2	3%	87%	82-85	Yes	1
29	2	3%	90%	86-89	Yes	1
30	5	7%	97%	90-94	Yes	1
31	2	3%	100%	95-99	Yes	1
<b>Sum</b>	<b>68</b>				21	10
<b>Month:</b> April	<b>Number of</b> <b>Complaints</b> <b>occurrence</b>	<b>Probability</b>	<b>Cumulative</b> <b>Probability</b>	<b>Random</b> <b>Number</b> <b>(2 Digit)</b>	<b>Yes / No</b>	<b>Logic</b>
1	0	0%	0%	00-02	No	0
2	0	0%	0%	03-05	No	0
3	5	15%	15%	06-08	Yes	1
4	5	15%	30%	09-11	Yes	1
5	2	6%	36%	12-14	Yes	1
6	1	3%	39%	15-17	Yes	1

7	1	3%	42%	18-20	Yes	1
8	0	0%	42%	21-23	No	0
9	0	0%	42%	24-26	No	0
10	3	9%	52%	27-29	Yes	1
11	5	15%	67%	30-32	Yes	1
12	0	0%	67%	33-35	No	0
13	3	9%	76%	36-38	Yes	1
14	0	0%	76%	39-41	No	0
15	0	0%	76%	42-44	No	0
16	0	0%	76%	45-47	No	0
17	2	6%	82%	48-50	Yes	1
18	2	6%	88%	51-53	Yes	1
19	0	0%	88%	54-56	No	0
20	0	0%	88%	57-59	No	0
21	0	0%	88%	60-62	No	0
22	0	0%	88%	63-65	No	0
23	0	0%	88%	66-68	No	0
24	0	0%	88%	69-71	No	0
25	3	9%	97%	72-74	Yes	1
26	0	0%	97%	75-77	No	0
27	1	3%	100%	78-80	Yes	1
28	0	0%	100%	81-83	No	0
29	0	0%	100%	84-86	No	0
30	0	0%	100%	87-99	No	0
31						
<b>Sum</b>	<b>33</b>				12	18
Month: May	Number of Complaints occurrence	Probability	Cumulative Probability	Random Number (2 Digit)	Yes / No	Logic
1	0	0%	0%	00-03	No	0
2	9	18%	18%	04-06	Yes	1
3	3	6%	24%	07-09	Yes	1
4	0	0%	24%	10-12	No	0
5	2	4%	29%	13-15	Yes	1
6	0	0%	29%	16-18	No	0
7	0	0%	29%	19-21	No	0
8	4	8%	37%	22-24	Yes	1
9	3	6%	43%	25-27	Yes	1
10	2	4%	47%	28-30	Yes	1

11	1	2%	49%	31-33	Yes	1
12	4	8%	57%	34-36	Yes	1
13	0	0%	57%	37-39	No	0
14	0	0%	57%	40-42	No	0
15	0	0%	57%	43-45	No	0
16	3	6%	63%	46-48	Yes	1
17	1	2%	65%	49-51	Yes	1
18	4	8%	73%	52-54	Yes	1
19	0	0%	73%	55-57	No	0
20	0	0%	73%	58-60	No	0
21	0	0%	73%	61-63	No	0
22	6	12%	86%	64-66	Yes	1
23	0	0%	86%	67-69	No	0
24	1	2%	88%	70-72	Yes	1
25	0	0%	88%	73-75	No	0
26	1	2%	90%	76-78	Yes	1
27	0	0%	90%	79-81	No	0
28	0	0%	90%	82-85	No	0
29	2	4%	94%	86-89	Yes	1
30	1	2%	96%	90-94	Yes	1
31	2	4%	100%	95-99	Yes	1
<b>Sum</b>	<b>49</b>				17	14
Month: June	Number of Complaints occurrence	Probability	Cumulative Probability	Random Number (2 Digit)	Yes / No	Logic
1	1	4%	4%	00-02	Yes	1
2	2	8%	12%	03-05	Yes	1
3	0	0%	12%	06-08	No	0
4	0	0%	12%	09-11	No	0
5	0	0%	12%	12-14	No	0
6	1	4%	16%	15-17	Yes	1
7	1	4%	20%	18-20	Yes	1
8	1	4%	24%	21-23	Yes	1
9	3	12%	36%	24-26	Yes	1
10	0	0%	36%	27-29	No	0
11	0	0%	36%	30-32	No	0
12	0	0%	36%	33-35	No	0
13	0	0%	36%	36-38	No	0
14	2	8%	44%	39-41	Yes	1

15	0	0%	44%	42-44	No	0
16	4	16%	60%	45-47	Yes	1
17	0	0%	60%	48-50	No	0
18	0	0%	60%	51-53	No	0
19	2	8%	68%	54-56	Yes	1
20	1	4%	72%	57-59	Yes	1
21	3	12%	84%	60-62	Yes	1
22	1	4%	88%	63-65	Yes	1
23	0	0%	88%	66-68	No	0
24	0	0%	88%	69-71	No	0
25	0	0%	88%	72-74	No	0
26	3	12%	100%	75-77	Yes	1
27	0	0%	100%	78-80	No	0
28	0	0%	100%	81-83	No	0
29	0	0%	100%	84-86	No	0
30	0	0%	100%	87-99	No	0
31						
<b>Sum</b>	<b>25</b>				13	17
<b>Month: July</b>	<b>Number of Complaints occurrence</b>	<b>Probability</b>	<b>Cumulative Probability</b>	<b>Random Number (2 Digit)</b>	<b>Yes / No</b>	<b>Logic</b>
1	0	0%	0%	00-03	No	0
2	0	0%	0%	04-06	No	0
3	1	2%	2%	07-09	Yes	1
4	1	2%	5%	10-12	Yes	1
5	2	5%	10%	13-15	Yes	1
6	3	7%	17%	16-18	Yes	1
7	2	5%	21%	19-21	Yes	1
8	0	0%	21%	22-24	No	0
9	0	0%	21%	25-27	No	0
10	0	0%	21%	28-30	No	0
11	2	5%	26%	31-33	Yes	1
12	3	7%	33%	34-36	Yes	1
13	0	0%	33%	37-39	No	0
14	1	2%	36%	40-42	Yes	1
15	0	0%	36%	43-45	No	0
16	0	0%	36%	46-48	No	0
17	4	10%	45%	49-51	Yes	1
18	1	2%	48%	52-54	Yes	1

19	0	0%	48%	55-57	No	0
20	2	5%	52%	58-60	Yes	1
21	4	10%	62%	61-63	Yes	1
22	0	0%	62%	64-66	No	0
23	0	0%	62%	67-69	No	0
24	2	5%	67%	70-72	Yes	1
25	1	2%	69%	73-75	Yes	1
26	2	5%	74%	76-78	Yes	1
27	1	2%	76%	79-81	Yes	1
28	5	12%	88%	82-85	Yes	1
29	0	0%	88%	86-89	No	0
30	0	0%	88%	90-94	No	0
31	5	12%	100%	95-99	Yes	1
<b>Sum</b>	<b>42</b>				18	13
<b>Month:</b> August	<b>Number of</b> <b>Complaints</b> <b>occurrence</b>	<b>Probability</b>	<b>Cumulative</b> <b>Probability</b>	<b>Random</b> <b>Number</b> <b>(2 Digit)</b>	<b>Yes / No</b>	<b>Logic</b>
1	1	1%	1%	00-03	Yes	1
2	3	4%	6%	04-06	Yes	1
3	1	1%	7%	07-09	Yes	1
4	3	4%	11%	10-12	Yes	1
5	0	0%	11%	13-15	No	0
6	0	0%	11%	16-18	No	0
7	6	8%	20%	19-21	Yes	1
8	1	1%	21%	22-24	Yes	1
9	3	4%	25%	25-27	Yes	1
10	3	4%	30%	28-30	Yes	1
11	5	7%	37%	31-33	Yes	1
12	0	0%	37%	34-36	No	0
13	0	0%	37%	37-39	No	0
14	0	0%	37%	40-42	No	0
15	2	3%	39%	43-45	Yes	1
16	8	11%	51%	46-48	Yes	1
17	1	1%	52%	49-51	Yes	1
18	3	4%	56%	52-54	Yes	1
19	0	0%	56%	55-57	No	0
20	0	0%	56%	58-60	No	0
21	7	10%	66%	61-63	Yes	1
22	6	8%	75%	64-66	Yes	1

23	4	6%	80%	67-69	Yes	1
24	3	4%	85%	70-72	Yes	1
25	3	4%	89%	73-75	Yes	1
26	0	0%	89%	76-78	No	0
27	0	0%	89%	79-81	No	0
28	5	7%	96%	82-85	Yes	1
29	2	3%	99%	86-89	Yes	1
30	1	1%	100%	90-94	Yes	1
31	0	0%	100%	95-99	No	0
<b>Sum</b>	<b>71</b>				21	10
<b>Month:</b> September	<b>Number of</b> <b>Complaints</b> <b>occurrence</b>	<b>Probability</b>	<b>Cumulative</b> <b>Probability</b>	<b>Random</b> <b>Number</b> <b>(2 Digit)</b>	<b>Yes / No</b>	<b>Logic</b>
1	5	7%	7%	00-02	Yes	1
2	0	0%	7%	03-05	No	0
3	0	0%	7%	06-08	No	0
4	3	4%	12%	09-11	Yes	1
5	3	4%	16%	12-14	Yes	1
6	1	1%	18%	15-17	Yes	1
7	1	1%	19%	18-20	Yes	1
8	3	4%	24%	21-23	Yes	1
9	0	0%	24%	24-26	No	0
10	0	0%	24%	27-29	No	0
11	5	7%	31%	30-32	Yes	1
12	2	3%	34%	33-35	Yes	1
13	6	9%	43%	36-38	Yes	1
14	7	10%	54%	39-41	Yes	1
15	5	7%	61%	42-44	Yes	1
16	0	0%	61%	45-47	No	0
17	0	0%	61%	48-50	No	0
18	2	3%	64%	51-53	Yes	1
19	3	4%	69%	54-56	Yes	1
20	9	13%	82%	57-59	Yes	1
21	0	0%	82%	60-62	No	0
22	3	4%	87%	63-65	Yes	1
23	0	0%	87%	66-68	No	0
24	0	0%	87%	69-71	No	0
25	4	6%	93%	72-74	Yes	1
26	2	3%	96%	75-77	Yes	1

27	2	3%	99%	78-80	Yes	1
28	0	0%	99%	81-83	No	0
29	1	1%	100%	84-86	Yes	1
30	0	0%	100%	87-99	No	0
31						
<b>Sum</b>	<b>67</b>				19	11
Month: October	Number of Complaints occurrence	Probability	Cumulative Probability	Random Number (2 Digit)	Yes / No	Logic
1	0	0%	0%	00-03	No	0
2	2	3%	3%	04-06	Yes	1
3	4	6%	9%	07-09	Yes	1
4	2	3%	12%	10-12	Yes	1
5	0	0%	12%	13-15	No	0
6	4	6%	18%	16-18	Yes	1
7	0	0%	18%	19-21	No	0
8	0	0%	18%	22-24	No	0
9	5	7%	25%	25-27	Yes	1
10	0	0%	25%	28-30	No	0
11	3	4%	29%	31-33	Yes	1
12	4	6%	35%	34-36	Yes	1
13	5	7%	43%	37-39	Yes	1
14	0	0%	43%	40-42	No	0
15	0	0%	43%	43-45	No	0
16	4	6%	49%	46-48	Yes	1
17	5	7%	56%	49-51	Yes	1
18	2	3%	59%	52-54	Yes	1
19	3	4%	63%	55-57	Yes	1
20	1	1%	65%	58-60	Yes	1
21	0	0%	65%	61-63	No	0
22	0	0%	65%	64-66	No	0
23	3	4%	69%	67-69	Yes	1
24	6	9%	78%	70-72	Yes	1
25	5	7%	85%	73-75	Yes	1
26	3	4%	90%	76-78	Yes	1
27	1	1%	91%	79-81	Yes	1
28	0	0%	91%	82-85	No	0
29	0	0%	91%	86-89	No	0
30	4	6%	97%	90-94	Yes	1

31	2	3%	100%	95-99	Yes	1
<b>Sum</b>	<b>68</b>				20	11
Month: November	Number of Complaints occurrence	Probability	Cumulative Probability	Random Number (2 Digit)	Yes / No	Logic
1	3	4%	4%	00-02	Yes	1
2	5	7%	12%	03-05	Yes	1
3	1	1%	13%	06-08	Yes	1
4	0	0%	13%	09-11	No	0
5	0	0%	13%	12-14	No	0
6	7	10%	24%	15-17	Yes	1
7	2	3%	27%	18-20	Yes	1
8	3	4%	31%	21-23	Yes	1
9	2	3%	34%	24-26	Yes	1
10	9	13%	48%	27-29	Yes	1
11	0	0%	48%	30-32	No	0
12	0	0%	48%	33-35	No	0
13	0	0%	48%	36-38	No	0
14	2	3%	51%	39-41	Yes	1
15	3	4%	55%	42-44	Yes	1
16	3	4%	60%	45-47	Yes	1
17	0	0%	60%	48-50	No	0
18	0	0%	60%	51-53	No	0
19	0	0%	60%	54-56	No	0
20	2	3%	63%	57-59	Yes	1
21	5	7%	70%	60-62	Yes	1
22	2	3%	73%	63-65	Yes	1
23	1	1%	75%	66-68	Yes	1
24	4	6%	81%	69-71	Yes	1
25	0	0%	81%	72-74	No	0
26	0	0%	81%	75-77	No	0
27	5	7%	88%	78-80	Yes	1
28	4	6%	94%	81-83	Yes	1
29	4	6%	100%	84-86	Yes	1
30	0	0%	100%	87-99	No	0
31						
<b>Sum</b>	<b>67</b>				19	11

Month: December	Number of Complaints occurrence	Probability	Cumulative Probability	Random Number (2 Digit)	Yes / No	Logic
1	0	0%	0%	00-03	No	0
2	0	0%	0%	04-06	No	0
3	0	0%	0%	07-09	No	0
4	6	11%	11%	10-12	Yes	1
5	3	5%	16%	13-15	Yes	1
6	2	4%	20%	16-18	Yes	1
7	0	0%	20%	19-21	No	0
8	0	0%	20%	22-24	No	0
9	0	0%	20%	25-27	No	0
10	0	0%	20%	28-30	No	0
11	1	2%	22%	31-33	Yes	1
12	4	7%	29%	34-36	Yes	1
13	3	5%	35%	37-39	Yes	1
14	1	2%	36%	40-42	Yes	1
15	2	4%	40%	43-45	Yes	1
16	0	0%	40%	46-48	No	0
17	0	0%	40%	49-51	No	0
18	5	9%	49%	52-54	Yes	1
19	3	5%	55%	55-57	Yes	1
20	6	11%	65%	58-60	Yes	1
21	5	9%	75%	61-63	Yes	1
22	2	4%	78%	64-66	Yes	1
23	0	0%	78%	67-69	No	0
24	0	0%	78%	70-72	No	0
25	0	0%	78%	73-75	No	0
26	4	7%	85%	76-78	Yes	1
27	1	2%	87%	79-81	Yes	1
28	6	11%	98%	82-85	Yes	1
29	1	2%	100%	86-89	Yes	1
30	0	0%	100%	90-94	No	0
31	0	0%	100%	95-99	No	0
<b>Sum</b>	<b>55</b>				17	14

## APPENDIX XII

### Number of Complaint Occurrence Per Day by Month

Number of Recurring Complaints in a Day (January)	Probability Recurring	Cumulative Probability	Random Number
0	41.94%	42%	00-42
1	12.90%	55%	43-55
2	12.90%	68%	56-68
3	16.13%	84%	69-84
4	6.45%	90%	85-90
6	3.23%	94%	91-94
7	3.23%	97%	95-97
8	3.23%	100%	98-99

Number of Recurring Complaints in a Day (February)	Probability Recurring	Cumulative Probability	Random Number
0	32.14%	32%	00-32
1	17.86%	50%	33-50
2	3.57%	54%	51-54
3	7.14%	61%	55-61
4	21.43%	82%	62-82
5	7.14%	89%	83-89
6	3.57%	93%	90-93
8	7%	100%	94-99

Number of Recurring Complaints in a Day (March)	Probability Recurring	Cumulative Probability	Random Number
0	32.26%	32%	00-32
1	6.45%	39%	33-39
2	25.81%	65%	40-65
3	9.68%	74%	66-74
4	12.90%	87%	75-87
5	6.45%	94%	88-94
6	3.23%	97%	95-97
9	3%	100%	98-99

Number of Recurring Complaints in a Day (April)	Probability Recurring	Cumulative Probability	Random Number
0	60.00%	60%	00-60
1	10.00%	70%	61-70
2	10.00%	80%	71-80
3	10.00%	90%	81-90
5	10.00%	100%	91-99

Number of Recurring Complaints in a Day (May)	Probability Recurring	Cumulative Probability	Random Number
0	45.16%	45%	00-45
1	16.13%	61%	46-61
2	12.90%	74%	62-74
3	9.68%	84%	75-84
4	9.68%	94%	85-94
6	3.00%	97%	95-97
9	3.00%	100%	98-99

Number of Recurring Complaints in a Day (June)	Probability Recurring	Cumulative Probability	Random Number
0	57%	57%	00-57
1	20%	77%	58-77
2	10%	87%	78-87
3	10%	97%	88-97
4	3%	100%	98-99

Number of Recurring Complaints in a Day (July)	Probability Recurring	Cumulative Probability	Random Number
	41.94%	42%	00-42

1	19.35%	61%	43-61
2	19.35%	81%	62-81
3	6.45%	87%	82-87
4	6.45%	94%	88-94
5	6.45%	100%	95-99

Number of Recurring Complaints in a Day (August)	Probability Recurring	Cumulative Probability	Random Number
0	32.26%	32%	00-32
1	16.13%	48%	33-48
2	6.45%	55%	49-55
3	22.58%	77%	56-77
4	3.23%	81%	78-81
5	6.45%	87%	82-87
6	6.45%	94%	88-94
7	3.23%	97%	95-97
8	3.23%	100%	98-99

Number of Recurring Complaints in a Day (September)	Probability Recurring	Cumulative Probability	Random Number
0	36.67%	37%	00-37
1	10.00%	47%	38-47
2	13.33%	60%	48-60
3	16.67%	77%	61-77
4	3.33%	80%	78-80
5	10.00%	90%	81-90
6	3.33%	93%	91-93
7	3.33%	97%	94-97
9	3.00%	100%	98-99
Number of Recurring Complaints in a Day (October)	Probability Recurring	Cumulative Probability	Random Number
0	35.48%	35%	00-35
1	6.45%	42%	36-42
2	12.90%	55%	43-55
3	12.90%	68%	56-68

4	16.13%	84%	69-84
5	12.90%	97%	85-97
6	3.23%	100%	98-99

Number of Recurring Complaints in a Day (November)	Probability Recurring	Cumulative Probability	Random Number
0	36.67%	37%	00-37
1	6.67%	43%	38-43
2	16.67%	60%	44-60
3	13.33%	73%	61-73
4	10.00%	83%	74-83
5	10.00%	93%	84-93
7	3%	97%	94-97
9	3.00%	100%	98-99

Number of Recurring Complaints in a Day (December)	Probability Recurring	Cumulative Probability	Random Number
0	45.16%	45%	00-45
1	12.90%	58%	46-58
2	9.68%	68%	59-68
3	9.68%	77%	69-77
4	6.45%	84%	78-84
5	6.45%	90%	85-90
6	9.68%	100%	91-99

## APPENDIX XIII

### Tables of Severity Spread by Months

Severity Level	Rating	Month January	Probability	Cumulative	Random Number
Insignificant	1	7	13%	13%	00-13
Minor	2	2	4%	16%	14-16
Moderate	3	17	30%	46%	17-46
Major	4	21	38%	84%	47-84
Critical	5	9	16%	100%	85-00
Sum		56	100%	100%	

Severity Level	Rating	Month February	Probability	Cumulative	Random Number
Insignificant	1	1	1%	1%	00-01
Minor	2	3	4%	6%	02-06
Moderate	3	43	62%	68%	07-68
Major	4	17	25%	93%	69-93
Critical	5	5	7%	100%	94-99
Sum		69	100%	100%	

Severity Level	Rating	Month March	Probability	Cumulative	Random Number
Insignificant	1	5	7%	7%	00-07
Minor	2	3	4%	12%	08-12
Moderate	3	38	56%	68%	13-68
Major	4	11	16%	84%	69-84
Critical	5	11	16%	100%	85-99
Sum		68	100%	100%	

Severity Level	Rating	Month April	Probability	Cumulative	Random Number
Insignificant	1	2	6%	6%	00-06
Minor	2	5	15%	21%	07-21
Moderate	3	11	33%	55%	22-55
Major	4	12	36%	91%	56-91
Critical	5	3	9%	100%	92-99
Sum		33	100%	100%	

Severity Level	Rating	Month May	Probability	Cumulative	Random Number
Insignificant	1	3	6%	6%	00-06
Minor	2	7	14%	20%	07-20
Moderate	3	22	45%	65%	21-65
Major	4	15	31%	96%	66-96
Critical	5	2	4%	100%	97-99
Sum		49	100%	100%	

Severity Level	Rating	Month June	Probability	Cumulative	Random Number
Insignificant	1	3	12%	12%	00-12
Minor	2	3	12%	24%	13-24
Moderate	3	13	52%	76%	25-76
Major	4	5	20%	96%	77-96
Critical	5	1	4%	100%	97-99
Sum		25	100%	100%	

Severity Level	Rating	Month July	Probability	Cumulative	Random Number
Insignificant	1	2	5%	5%	00-05
Minor	2	5	12%	17%	06-17
Moderate	3	27	64%	81%	18-81
Major	4	6	14%	95%	82-95
Critical	5	2	5%	100%	96-99
Sum		42	100%	100%	

Severity Level	Rating	Month August	Probability	Cumulative	Random Number
Insignificant	1	3	4%	4%	00-04
Minor	2	4	6%	10%	05-10
Moderate	3	47	66%	76%	11-76
Major	4	11	15%	92%	77-92
Critical	5	6	8%	100%	93-99
Sum		71	100%	100%	

Severity Level	Rating	Month September	Probability	Cumulative	Random Number
Insignificant	1	9	13%	13%	00-13
Minor	2	4	6%	19%	14-19
Moderate	3	42	63%	82%	20-82
Major	4	12	18%	100%	83-99
Critical	5	0	0%	100%	
Sum		67	100%	100%	

Severity Level	Rating	Month October	Probability	Cumulative	Random Number
Insignificant	1	6	9%	9%	00-09
Minor	2	6	9%	18%	10-18
Moderate	3	35	51%	69%	19-69
Major	4	15	22%	91%	70-91
Critical	5	6	9%	100%	92-99
Sum		68	100%	100%	

Severity Level	Rating	Month November	Probability	Cumulative	Random Number
Insignificant	1	4	6%	6%	00-06
Minor	2	10	15%	21%	07-21
Moderate	3	47	70%	91%	22-91
Major	4	5	7%	99%	92-99
Critical	5	1	1%	100%	100-99
Sum		67	100%	100%	

Severity Level	Rating	Month December	Probability	Cumulative	Random Number
Insignificant	1	9	16%	16%	00-16
Minor	2	4	7%	24%	17-24
Moderate	3	35	64%	87%	25-87
Major	4	4	7%	95%	88-95
Critical	5	3	5%	100%	96-99
Sum		55	100%	100%	

## APPENDIX XIV

### Example of The Simulation Distribution Table

Days	Random Number	Occurance (Yes/No)	Random Number	Numbers of Complaints / Day	RN 1	RN 2	RN 3	RN 4	RN 5	RN 6	RN 7	RN 8	RN 9	RN 10	RN 11	RN 12	24 Digit Random Number	Severity Type 1	Severity Type 2	Severity Type 3	Severity Type 4	Severity Type 5	Total Number of Days Solved (Without CMMS) (Occurance * Avg Days Severity)	Total Number of Days Solved (With CMMS) (Occurance * Avg Days Severity)
1	41	No	35	0	0	0	0	0	0	0	0	0	0	0	0	0	0000000000	0	0	0	0	0	0	0
2	3	Yes	98	8	4	19	0	1	84	31	57	8	0	0	0	0	41901843157880000	3	0	2	2	0	126	112
3	7	Yes	32	0	0	0	0	0	0	0	0	0	0	0	0	0	0000000000	0	0	0	0	0	0	0
4	81	No	54	0	0	0	0	0	0	0	0	0	0	0	0	0	0000000000	0	0	0	0	0	0	0
5	46	Yes	6	2	6	31	0	0	0	0	0	0	0	0	0	0	66310000000000	0	0	1	1	0	45	41
6	3	Yes	75	3	1	12	46	0	0	0	0	0	0	0	0	0	11246000000000	2	0	1	0	0	50	44
7	45	Yes	92	6	52	11	9	11	62	82	0	0	0	0	0	0	521199116282000000	2	0	0	3	0	81	71
8	5	Yes	89	4	38	71	56	8	0	0	0	0	0	0	0	0	3871568000000000	1	0	1	2	0	76	68
9	98	No	56	0	0	0	0	0	0	0	0	0	0	0	0	0	0000000000	0	0	0	0	0	0	0
10	62	No	65	0	0	0	0	0	0	0	0	0	0	0	0	0	0000000000	0	0	0	0	0	0	0
11	46	Yes	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0000000000	0	0	0	0	0	0	0
12	50	Yes	80	3	47	94	24	0	0	0	0	0	0	0	0	0	4794240000000000	0	0	1	1	0	45	41
13	3	Yes	32	0	0	0	0	0	0	0	0	0	0	0	0	0	0000000000	0	0	0	0	0	0	0
14	35	Yes	37	0	0	0	0	0	0	0	0	0	0	0	0	0	0000000000	0	0	0	0	0	0	0
15	8	Yes	9	8	8	62	82	39	83	26	30	84	0	0	0	0	8628239832630840000	1	0	3	4	0	166	150

## APPENDIX XV

### Yearly Iteration Table for 2023

Month	Average Number of Complaint per Day	Monthly Standard Deviation	Average Severity Type 1	Average Severity Type 2	Average Severity Type 3	Average Severity Type 4	Average Severity Type 5	Average of Complaint Days		Improvement Percentage (%)
								Before CMMS	With CMMS	
January	1.45	1.93	6	2	14	19	0	21.00	18.30	13%
February	1.68	2.31	1	1.7	32.3	13.4	2.8	24.00	21.50	10%
March	1.56	2.08	4.5	2.3	25.4	8.2	7.9	22.90	20.60	10%
April	0.53	1.28	1.2	2	6.3	5.4	0.9	22.10	19.40	12%
May	0.82	1.64	2.2	4.7	12.2	8	0.7	22.20	19.80	11%
June	0.29	0.70	1.2	2	4.7	1.5	0.4	22.00	19.60	11%
July	0.63	1.16	1.1	2.7	12.2	3.1	0.4	23.90	21.40	10%
August	1.57	2.11	2.5	2.7	33.1	7.8	3.5	24.10	21.60	10%
September	1.19	1.80	4.4	2.3	24	6.1	0	23.20	20.80	10%
October	1.51	1.86	4.7	5.2	23.3	12	3.8	22.50	19.90	12%
November	1.26	1.82	2.4	3.9	28.4	3.8	0.4	24.30	22.00	9%
December	0.98	1.80	5.5	2.7	20.4	3.2	1	22.80	20.50	10%
<b>Average</b>	1.12	1.71	3.07	2.83	19.65	7.64	1.82	22.92	20.45	11%

## APPENDIX XVI

### Invitation Letter for Focus Group Discussion (FGD)

www.uitm.edu.my



Institut  
Pengangkutan  
Malaysia

Surat kami : UiTM.600-9/1/8  
Tarikh : 6 Mei 2025

TUAN IR. HANIFF BIN AB HAMID  
Ketua Jurutera Elektrik Negeri Selangor  
Tingkat 3, Pejabat Cawangan Kejuruteraan Elektrik,  
Kompleks Ibu Pejabat JKR Selangor  
Persiaran Jubli Perak, Seksyen 17  
40200 Shah Alam, Selangor

Tuan,

#### JEMPUTAN KE PERBINCANGAN PETANG AKADEMIK MITRANS: KUMPULAN FOKUS BERKENAAN PENYELIDIKAN TERKINI DALAM BIDANG PENGANGKUTAN DAN LOGISTIK

Dengan segala hormatnya perkara di atas adalah dirujuk.

2. Sukacitanya Institut Pengangkutan Malaysia (MITRANS) Universiti Teknologi MARA (UiTM) menjemput tuan sebagai Panel Perbincangan Kumpulan Fokus bertajuk: "Kajian Kebolehlaksanaan Sistem Pengurusan Penyelenggaraan Berkomputer (CMMS) bagi Sistem Pemantauan Aset Elektrik Jalan Raya yang Bersepadu".

3. Butiran program adalah seperti berikut:

Tarikh : 15 Mei 2025 (Khamis)  
Masa : 2:00 petang – 5:00 petang  
Tempat : Bilik Mesyuarat Ar Rahman,  
Institut Pengangkutan Malaysia (MITRANS),  
Universiti Teknologi MARA, Shah Alam.

4. Pihak kami berharap sesi ini dapat menjadi wadah kepada perbincangan yang berilmiah dan bermanfaat, serta membantu para pelajar untuk memperluas pengetahuan mereka dalam bidang berkaitan. Bersama-sama ini dilampirkan tentatif program untuk rujukan tuan.

... 2/-

Universiti Teknologi MARA  
40450 Shah Alam, Selangor, MALAYSIA  
Tel: (+603) 5544 2351/2352/2348/2343  
Faks: (+603) 5544 2344  
E-mel: [mitrans@uitm.edu.my](mailto:mitrans@uitm.edu.my)  
[www.mitrans.uitm.edu.my](http://www.mitrans.uitm.edu.my)




Surat kami : UiTM.600-9/1/8

5. Kami amat menghargai kesudian tuan untuk turut serta dalam program ini dan berharap kerjasama ini dapat diteruskan demi masa depan negara yang lebih cemerlang.

Sekian, terima kasih.

**"MALAYSIA MADANI"**  
**"BERKHIDMAT UNTUK NEGARA"**

Saya yang menjalankan amanah,



(PROF. MADYA DR. WAN MAZLINA WAN MOHAMED)  
Pengarah

s.k: Prof Madya Ts. Dr. S. Sarifah Radiah Shariff  
Timbalan Pengarah, MITRANS

## APPENDIX XVII

### Text For Focus Group Discussion (Section A: Unified Systems Overview)

#### Question 1

*REACT is a monitoring platform for road electrical assets but lacks maintenance components. In your experience, how critical is it to have maintenance information integrated directly within the REACT system rather than as a separate system?*

#### Panel 2

From what I know, REACT functions like a modem - it collects data, has storage, and connects to the cloud for system automation. It features sensors such as loop sensors, wireless vehicle detectors, radar, and AI cameras to optimize traffic flow. In the past, systems like SCOOT used loop sensors to count vehicles and coordinate traffic. With AI today, adjustments can be made in real time based on traffic conditions, saving time and making traffic smoother.

#### Panel 3

Right now, we only know whether the system is working or not. We don't know the reasons behind failures. That's what's missing. We need to add more elements to REACT. Since it only tells us "working" or "not working," our response is delayed.

#### Panel 2

The benefit is, with REACT and AI cameras, we can gather traffic statistics, identify vehicle types, and monitor problematic vehicles—so we don't need to conduct physical traffic counts anymore.

#### Panel 1

Back in 2012-2013, before REACT, we used an SMS-based system. For example, if someone opened a TNB service door, we would receive a notification about unauthorized access or theft. We kept upgrading the system until we got to REACT, which has been very helpful in monitoring our JKR assets.

#### Panel 5

If you ask me for advice, yes—it's essential. Having this integration helps with our monitoring efforts. Ideally, we should be able to click on one platform and immediately see whether an asset is due for maintenance.

#### Panel 4

My expectations for REACT were high. For example, I imagined pressing a button and

instantly seeing the light's battery level or confirming if it's functioning. But those features are not there. So yes, I would say it's lacking.

**Panel 2**

In Klang, we're not yet at the stage where we can fully benefit from REACT. A lot of our equipment is still old. It's better if we focus on upgrading to newer controllers first.

**Panel 5**

I agree. For older systems, just leave them as they are. Focus on upgrading and integrating the new systems into REACT. It's more cost-effective that way.

**Panel 2**

The goal in Selangor is to reduce the number of malfunctions. For now, we should prioritize new products and controllers.

**Panel 3**

If it's a new asset, integration is fine.

**Panel 4**

Exactly. For new assets, we fully agree. They can be registered in the system immediately, and we'll be able to tell exactly when they fail. That would help a lot. Right now, we often rely on public complaints, and sometimes they're not even accurate. With maintenance integration, we can confirm from the system if a light is truly not working instead of wasting time investigating a false complaint.

**Question 2**

*What specific maintenance data would be most valuable to have accessible from within the REACT platform to improve your daily operations?*

**Panel 5**

Ideally, we should be able to see voltage levels for each phase, current flow, and any abnormalities. If the system shows that, we can already anticipate what kind of issue might be happening on site. Also, we should be able to track the lifespan of each component like lanterns or solar panels.

**Panel 2**

Yes, that's right. Vendors usually give a 5-year lifespan for batteries. If REACT can display that information, we'd know when to replace them.

**Panel 3**

Also, information about vandalism would be useful. We face a lot of vandalism. It would help if the system could detect when a door is opened or if there's CCTV input

detecting unauthorized access.

**Panel 2**

Yes, features like that are often overlooked.

**Panel 3**

And interference from third parties—contractors or equipment accidentally damaging our assets during nearby work.

**Panel 1**

We have plans, but federal budget constraints make it hard to get everything we want.

**Panel (MITRANS)**

So, we're talking about suspicious activity detected by the camera—like a backhoe hitting a pole?

**Panel 3**

Yes, exactly. If there's physical contact, it should be detected.

**Panel 2**

That's a good feature to have.

**Panel 3**

It should be included in REACT.

**Panel (MITRANS)**

There were mentions about delays in response time. What's causing that?

**Panel 2**

Right now, we get complaints from many different places.

**Panel 3**

Yes, multiple causes.

**Panel (MITRANS)**

So, the number of complaints exceeds staff capacity?

**Panel 3**

Yes, especially for streetlights.

**Panel (MITRANS)**

Also, traffic delays can prevent quick response to reported damage?

**Panel 1**

Exactly.

**Panel 2**

The reasons are simple. We just don't have enough staff or budget. In my area, the more advanced features are probably better suited for other districts.

**Panel 3**

Sometimes we can't even access the site at the reported time.

**Panel 2**

For traffic lights, we're required to resolve issues within 24 hours.

**Panel 1**

Yes, that's right.

**Panel (MITRANS)**

So there's 24-hour standby?

**Panel 2**

We're not officially on standby, but we always respond when called.

**Panel 1**

Once there's a complaint, we have to attend to it—no matter what.

**Panel 2**

Yes, that's how we operate.

**Panel (MITRANS)**

Even at night?

**Panel 2**

Yes, same procedure. There's no shift system. We just go when we're called.

**Panel 1**

That's why if REACT could notify us about issues before complaints are made, it would be ideal.

**Panel 2**

REACT would be excellent if we had sufficient funding.

**Panel 4**

That's exactly what I'm proposing—we should be able to track operational status, like battery percentages dropping, so we can prepare budgets and forecast failures.

## APPENDIX XVIII

### Text For Focus Group Discussion (Section B: Submerging into Technical)

#### Question 1

*Based on the five key CMMS components presented (work order management, asset management, maintenance management, inventory control, and reporting management), which do you believe would deliver the most immediate value to PWD operations?*

#### Panel (MITRANS)

In CMMS, there are five components work order management, asset management, maintenance management, inventory control, and reporting management.

#### Panel (MITRANS)

From these five key components, if we want to make improvements, which one should we prioritize first? Because we can't implement them all at once.

#### Panel 2

In my experience, for cabling - I would say maintenance management.

#### Panel (MITRANS)

So, good maintenance management, yes.

#### Panel 3

That's right. If maintenance management is already efficient, then the rest should follow smoothly.

#### Panel 2

From our experience, we first look at the cables and controllers.

#### Panel (MITRANS)

Like whether the cables are damaged?

#### Panel 2

Yes, if there's a short circuit, we'll cut the road and rebuild the line.

#### Panel (MITRANS)

All responses are anonymous.

#### Panel 2

Yes, every area has its own condition.

#### Panel 1

For example, in Petaling, we took over work from PLUS. On FT02 Federal Highway,

many of the cables are still from the 1980s, and they're still in use. So, aside from vandalism, the main factor is aging infrastructure—it needs replacement.

#### **Panel 2**

The complaints we receive are mostly about non-functioning signals—green or amber not lighting up. Faults like LEDs not lighting, timing issues, phasing, or fault timing. If there's damage, the system will log it under fault time. Most public complaints just report whether it works or not, or whether bulbs are out. A single intersection has 4 indicators—2 primary, 2 secondary. Sometimes overhead lights, left, right, lower sides. Overseas, they don't have as many aspects as we do. If one side is hit, we still have other sides working—until only one remains.

#### **Panel 4**

If I put myself in this situation, I would say the most important is **asset management**. Because, say at night, if a state electrical director or top management asks which lamp is out—we don't have the exact location. Our assets are not well managed. Even if someone shares a picture of a pole, I still have to refer to the district OIC (officer in charge) to confirm whether it's ours. Sometimes, even the OIC isn't sure. Same with feeder pillars—if TNB calls about unpaid bills, I don't even know if the meter belongs to us or the local council. There's no tagging system. So if you ask me, the most important is asset management.

#### **Panel 5**

I can see the problem now—assets are not listed in inventory. If the director or district engineer asks, "How many lamps are there in Hulu Langat?"—we can't answer. I once suggested having a workshop, maybe in Langkawi where we won't be disturbed. I see that as critical. We can't even access how many lights we have. So, asset and inventory management are more important. From asset data, we'd know when it was installed. For example, if something starts to fail in year five, we'd understand why. But for someone like me, who just joined a year ago, I have no idea when assets were installed. Now solar units are starting to fail, but there's no baseline info.

#### **Panel 4**

Just this morning during a technical talk, a supplier asked me, "How many streetlights are there in Selangor?" I couldn't answer. There's no figure, because we don't register them. It's not my team's fault—we don't have a CMMS. At best, we put a sticker. OIC might know, but if I need the exact number, I'll have to ask 10 different people.

**Panel 5**

It's easier to manage if it's not just a single component. From my higher-level view, I'd say asset management is most important. But the frontliners—the ones on the ground—will prioritize maintenance because that's what they deal with. Everyone has different scopes and constraints.

**Panel 3**

Asset management could be the top component, and the others can fall under it.

**Panel 4**

From my point of view, all components are important.

**Question 2**

*How customized should the CMMS features be for PWD's specific workflows, and what unique operational requirements must be addressed in the system design?*

**Panel (MITTRANS)**

From the five components earlier, maintenance management should be our focus. What improvements can we make to make the system more efficient and unique?

**Panel 3**

From the asset data—if we know the age of each asset—we can determine the arising problems. If we don't know the age, we can't predict issues.

**Panel 2**

For me, the best way to integrate with REACT is through AI cameras. That's most important to me because it already includes loop sensors, wireless vehicle detectors, and infrared.

**Panel 2**

If there's a budget, anything can happen.

**Panel 4**

I agree with that. Budget is key. The simplest would be QR code stickers—you scan and instantly get location, district, installation date, key-in date—just like what TNB does. But to do that requires a system and internet—so again, budget.

**Panel 2**

If we have the budget, even the most advanced features can be realized. Management can also easily calculate the total cost.

**Panel (MITRANS)**

A key feature should be real-time information. If you use QR codes, what information is shown must be real-time. All districts in Selangor need to update their lamp counts. So when management asks, the system can give real-time answers.

**Panel 5**

Yes, that's the kind of info we need. Real-time updates are a must when developing CMMS. Upper management always wants info immediately.

**Panel 3**

It should be easy to access and edit. For example, if a pole is knocked over, we should be able to update that in the system easily.

**Panel 4**

Easy to manage.

**Panel 5**

Easy to edit—especially when assets like poles are no longer in use.

## APPENDIX XIX

### Text For Focus Group Discussion (Section C: Complaint Resolutions)

#### Question 1

*The simulation shows that eliminating two hierarchical steps in the complaint management process could reduce resolution time by approximately 11%. Based on your experience, is this improvement significant enough, and are these specific steps appropriate to eliminate?*

#### Panel 3

If your system can address the issues we currently face in the SISPAA system, that would be good. First, SISPAA is slow, and second, it's repetitive. Sometimes, the same location gets reported by multiple people—five complaints for the same site. That repetition is what causes the number to go up to over 600. If CMMS can solve this, then yes, it's acceptable.

#### Panel 4

Which two steps exactly are you eliminating? The screening process from JKR Malaysia and the Complaint Management Division of JKR?

#### Panel 4

Just calculate 11% of 7 days—how many days is that?

#### Panel 2

Do you mean completing the complaint reply or completing the repair?

#### Panel (MITRANS)

Only the complaint reply.

#### Panel 4

Okay, in SISPAA we must close and respond within 7 days. If 11% of 7 days is equivalent to one day, then yes, you're saving one day and making it easier for us to close complaints. Do you think that's worthwhile?

#### Panel (MITRANS)

I think it is worthwhile, but I feel like there's not enough information.

#### Panel 4

11%? Hmm. 11%) is okay, but not enough in my opinion. Maybe we could eliminate two or three more steps.

#### Panel 5

Because the impact isn't very big—if we go from 7 to 6 days, it's not that noticeable.

**Panel 4**

Regarding complaint status, if the Director or KP JKR wants to know—if CMMS could send it straight to the State Electrical Engineer, or the Officer in Charge, or even Panel 1—it could save us a day. That extra day gives us buffer time. If we go to repair the next day, it won't feel rushed. Now, with this setup, you're saving us one full day.

**Panel 5**

So, you're saying within 7 days the repair is done?

**Panel (MITRANS)**

For major complaints, the target is 14 days. Our simulation shows an average of 23 days. So even with improvements, we're still exceeding the 14-day threshold.

**Panel 3**

Let me give an example. A complaint logged today (let's say May 5th) only reached me on May 15th. So yes, there's a delay.

**Panel (MITRANS)**

An important note, Complaints are often received beyond the customer charter's time limit.

**Panel 3**

My complaints come through the complaints officer.

**Panel 2**

For mine, they come directly to the boss.

**Panel 4**

Your complaints go directly to JKR Klang. But Panel 3's complaints go through the Selangor State Complaints Division.

**Panel 2**

Yes, mine come directly through email.

**Panel 4**

So, what Amjad meant is this if the complaint is for JKR Klang, it goes directly to JKR Klang. But if it's routed to JKR Selangor, it goes through the Director, JPB, JAP J—then finally to the Officer in Charge. That's bureaucracy.

**Panel 5**

So, if it's under Panel 2's district, it's faster?

**Panel 2**

Yes, because I was officially appointed as the Complaints Officer for Klang.

**Panel 4**

Exactly. If the complaint goes straight to the District Engineer of Klang, it's faster. If it goes through JKR Selangor, it loops around first.

**Panel 5**

It's the same with other districts—if it goes straight to the right officer, it's faster and easier.

**Panel 2**

So far, I'm the only OIC who also acts as the complaints officer.

**Panel 4**

So that's why we're saying—if we can eliminate two or three more steps, it would really help.

**Additional Sharing****Panel 4**

Let me throw in a real case—this happened in Gombak. A beloved putu mayam street vendor fell into a pothole and passed away. The blame wasn't on the pothole but the streetlight not working. They said the accident happened because the light wasn't functioning. If MITRANS were there, who would be at fault? Maybe we could collaborate on this. It's not fair if we get blamed. This is an example of how varied cases in Selangor can be. Use this as a school of thought—a benchmark or case study.

**Question 2**

*How would having access to historical maintenance records affect your team's ability to diagnose and respond to complaints more efficiently?*

**Panel 4**

It would help a lot. Let's say I receive a complaint and I call Panel 2 about a problem at a roundabout. If he says it's raining and suspects a trip or leakage—we can verify that based on history. If this has happened before, we can identify the pattern. We'd know the answer on the spot without waiting for site results or inspections.

**Panel (MITRANS)**

If we already know that the same issue keeps recurring at the same location, why don't we think about a long-term fix? Preventive measures?

**Panel 1**

Budget constraints.

**Panel 2**

Budget.

**Panel 5**

Also budget.

**Panel 3**

But in electrical systems, sometimes when it fails, it's for safety. If the system keeps running, it could get further damaged. So the protection system must be in place.

**Panel 4**

Before I was here, I was in JKR Kuala Lumpur managing building maintenance—there were no streetlights or traffic lights. The most complaints came from police stations and schools. Let me give you an example. In a teacher's room with two sockets and eight teachers, they kept plugging in more extensions. Eventually, the power would trip. If we told them not to do that, they'd say, "Then how can we work?" Same with the police stations—plugging in everything late into the night. When we told them no, they said, "Then how can we operate?" It's about survival needs. Same here in JKR Selangor. We light up things to keep them running—even with limited budget. If not, we get blamed.

**Panel 2**

Exactly.

**Panel 4**

Like the earlier story of the streetlight blamed for the pothole accident—or a traffic light not working causing an accident. They might even stand in front of our doors asking for compensation. It's all about survival continuity.

**Panel 4**

Our OICs (Officers in Charge) handle directories. We have 9 OICs—one for each district. When there's a recurring trip or fault, they'll prepare a list for me and say "Please include this in the next budget." But usually, they each submit 10 items, and out of 90 total, maybe only 30 to 50 jobs get funded due to budget limitations. Again—survival continuity.

**Additional**

**Panel 4**

Prof, I don't know how far this conversation will go, but honestly, I feel relieved. All these problems—I've never had a proper platform to raise them. Usually, it's just "ask

for RM10, get RM3, and make do." But today I got to say it, even if it's just between these four walls.

**Panel (MITRANS)**

Yes, it's for academic purposes. We'll write the thesis. When it comes time to publish, we'll check whether it's allowed. We'll generalize everything.

**Panel 4**

Let's preview the publication first—even anonymously, it might still resemble real government officers.

**Panel (MITRANS)**

All the problems stated are based on thematic analysis only. No sentiment analysis, and the opinions are from the organization, not individuals. We'll acknowledge CKE and generalize the context to street lighting maintenance.

**Panel 4**

If it doesn't jeopardize the organization, position, or responsibilities, and doesn't bring shame to CKE HQ or KKR, it should be fine.







## APPENDIX XX

### 5<sup>th</sup> Malaysia International Logistic & transport Conference (MILTC), 2023 at Dewan Sivik Petaling Jaya City Council

5th MITRANS INTERNATIONAL LOGISTICS AND TRANSPORT CONFERENCE (MILTC2023)  
20 December 2023

#### THE FEATURES OF THE UNIFIED INTERGRATED ASSET MONITORING SYSTEM FOR MONITORING MULTIPLE TYPE OF ROAD ELECTRICAL ASSET

Aiiiii Amjad Bin Abdul Wahid<sup>1\*</sup>, S. Sarifah Kadlah Shariff<sup>7</sup>

*Malaysia Institute of Transport (MITRANS), Vntmill Teknologi MARA (VITM), 40450 Stall Alam, Selangor, Malaysia*  
*Malaysia Institute of Transport (MITRANS), Vnhvrsiti Trknologi MARA (VITM), 40450 Shah Alan, Selangor, Malaysia*

{ thtryxndninfiauthor am.iramjadwahkk\*Bmail.com

#### Abstract

Road Assets monitoring systems allow personnel to monitor real-time performance of asset and fault management detection. This article determines the characteristics of a unified integrated monitoring system to allow multiple type of asset with different roles to be easily monitored. The approach will allow easy data collection, group monitoring, overall asset assessment and method for open integration for multiple road electrical assets. From (be analysis of findings, we propose a key concept and criterion of a Unified System which are categorized from similar field and functions which allow easy monitoring. Three major factors include Types of Assets, various Sources of Supplier Brands and Easy Maintenance. The implication of this study holds a significant value which supports smart city initiatives, enhances road safety, and optimizes asset management. The adoption of a unified system can improve urban Infrastructure efficiency In real time asset downtime and decision-making. Moreover, efficient maintenance practices can be implemented by having the right monitoring system and contribute to more effective road network and aligning with urban development ultimately providing safer with more efficient road networks. The exploration of study offers fresh insights into an integrated and unified monitoring system adding value to stake holders especially road maintenance organization about the potential benefits and implications of similar systems, ultimately contributing to more efficient, safer, and technologically advanced road infrastructure.

Keywords: unified system, integrated asset system, asset management system, smart city infrastructure, road monitoring system

#### Introduction

With the presence of industrial revolution 4.0, technologies have moved to a web based or internet of things architecture system, providing opportunities for improved asset monitoring and management practices. The emergence of many monitoring software and programs have indeed benefited various organizations including road infrastructure managers or any kind of asset manager and asset management organization. Die real time status of asset viewing, or asset controlling have become more convenient and efficient with access through mobiles and laptops have also made it easier for managers to monitor assets remotely and make informed decisions in a timely manner. For road infrastructure managers or organizations, the use of an electrical asset monitoring system becomes crucial in ensuring the proper functioning of electrical assets such as street lighting and traffic signal or other related road assets.

However, with the wide range of road assets suppliers and their diverse monitoring and management requirements, the technology has become more complex and fragmented. Different systems are built to cater for each function, which results in inefficiencies and difficulties in management, data integration and analysis. For instance, potholes or road damage should not be in a different category than pavements and drainage, electrical system should include cable management, traffic lights and street lightings together, while signage and markings should be concurrently to provide optimum road efficiencies. Asset monitoring and asset management on the other hand should be under in one arch of a system. Having different systems and different applications or software will result in lower productivity, increasing civil costs, and in cohesive decision making.

A unified integrated asset monitoring and management system is a solution to address the challenges posed by the complex and fragmented nature of road infrastructure assets, especially electrical assets. Unified integrated asset monitoring systems play a vital role in the effective management of multiple types of road assets which will immensely be beneficial in terms of various suppliers, efficiency, cost savings and decision making. Organization of road infrastructure managers will deeply benefit from having a unified system that consolidates all asset monitoring and management functions into one

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The Chmtcrd  
Institute of Logistics  
and Transport

# CERTIFICATE OF APPRECIATION

This e-certificate is proudly presented to

**AMAR AMJAD ABDUL WAHID**

as a PRESENTER at

**5<sup>th</sup> MILTC2023**

**MITRANS International Logistics and  
Transport Conference**

on

**Date: 20th December 2023**

**Venue: Dewan Sivik Petaling Jaya City Council**

Organised by:

Malaysia Institute of Transport (MITRANS), UiTM

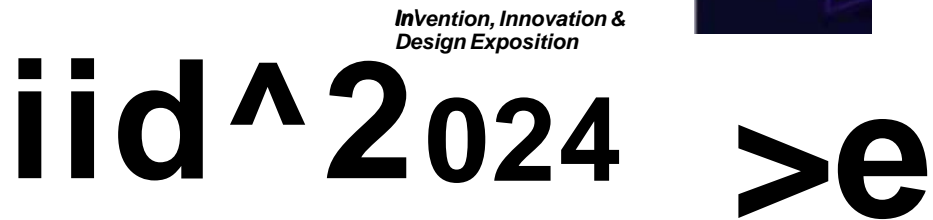
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APPENDIX XXI

Invention, Innovation and Design Exposition (IIDEX) 2024



Heartiest Congratulations to

S.SARIFAH RADIAH SHARIFF  
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MUHAMAD SAFUAN BIN SHAMSHOL BAHRI  
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on the successful achievement of

Title: An Ingenious Priority Determination for Sustainable Port (**AI\_0SP**)

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**Title: An Ingenious Priority Determination for Sustainable Port (AIDSPi**

in recognition of participation in iidex2024

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## APPENDIX XXII

**16th IEEE Control & System Graduate Research Colloquium (ICSGRC) 2025 at  
Mardhiyyah Hotel Shah Alam Malaysia**

# Optimizing Electrical Complaints Resolution Through CMMS: A Monte Carlo Simulation Approach

Amar Amjad Bin Abdul Wahid  
Malaysian Institute of Transport  
(MITRANS)  
Universiti Teknologi MARA  
(UITM)  
40450 Shah Alam, Malaysia  
amaramjadwahid@gmail.com

S. Sarifah Radiah Shariff  
Malaysian Institute of Transport  
(MITRANS)  
Faculty of Computer and Mathematical  
Science,  
Universiti Teknologi MARA  
(UITM)  
40450 Shah Alam, Malaysia  
shari990@uitm.edu.my

Ilyas Masudin  
Department of Industrial Engineering  
University of Muhammadiyah Malang,  
Malang 65144, Indonesia  
masudin@umm.ac.id

**Abstract**— Resolving electrical complaints quickly is important for the Public Works Department (PWD), Malaysia, which aims to meet response times set in its Customer Charter. However, the current hierarchical process often causes delays. This study explores how a Computerized Maintenance Management System (CMMS) can improve efficiency by using Monte Carlo simulation to compare complaint handling with and without the system. It looks at how often complaints occur, how many are received daily, and how severe they are, and compares the average resolution time in each case. The results show that a CMMS can reduce the average resolution time from 23 days to 20.9 days or approximately a 11% improvement. This highlights the system's potential to improve maintenance efficiency, better allocate resources, and deliver faster service for road electrical issues.

**Keywords:** Electrical Complaints, CMMS, Monte Carlo Simulation, Complaint Resolution, Maintenance Efficiency

### I. INTRODUCTION

Electrical complaints are a critical issue as they directly impact public safety and infrastructure reliability. The Public Works Department (PWD) of Malaysia follows the Piagam Pelanggan (Customer Charter), which establishes service commitments, including the expected response time for resolving complaints. The completion period for electrical works is categorized based on complexity: common damages should be repaired within 1 day, while more complex issues may take up to 7 days [1]. However, in practice, the complaint resolution process is often delayed due to hierarchical approval layers, inefficient coordination among teams, and budgeting constraints. The current manual or semi-automated system for handling complaints requires multiple approvals and procedural steps, leading to inefficiencies in addressing issues promptly. This hierarchical structure increases the time required to assess, assign, and resolve complaints. An analysis of the existing complaint management process reveals that complaints received at headquarters or state levels already experience a two-day delay before reaching maintenance teams based on Figure 1.

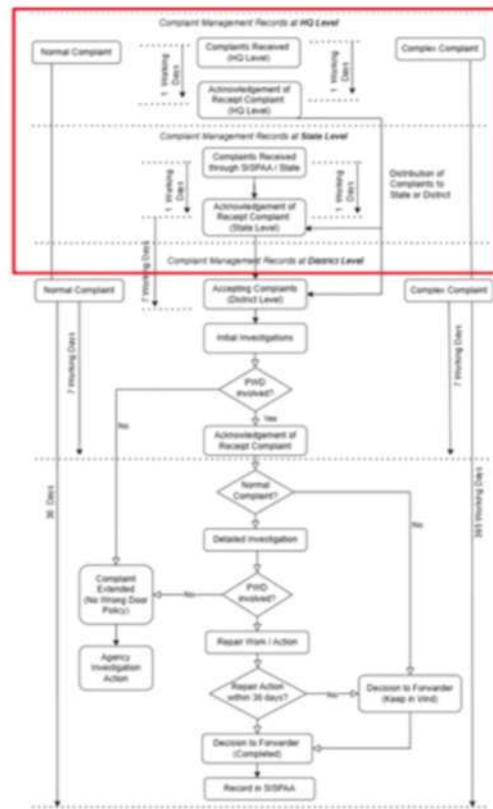


Fig. 1. Flow Chart of a Public Complaint Registration

There is a need to explore alternative solutions that streamline the complaint resolution process, ensuring faster and more effective responses to electrical issues. One such solution is the Computerized Maintenance Management System (CMMS), which offers a centralized structured approach to managing complaints, work orders, and resource

# ICSGRC 2025



## CERTIFICATE OF PARTICIPATION

This certifies that

**Amar Amjad Abdul Wahid, S.Sarifah Radiah Shariff, Ilyas Masudin**

have successfully presented the paper with the title of

**Optimizing Electrical Complaints Resolution Through CMMS:  
A Monte Carlo Simulation Approach**

in 2025 16<sup>th</sup> IEEE Control & System Graduate Research Colloquium (ICSGRC 2025)  
on 2<sup>nd</sup> of August 2025



PROF. DR. RAMLI ADNAN  
General Chair  
ICSGRC 2025



# ICSGRC 2025



## CERTIFICATE OF PRESENTER

This certifies that

**Amar Amjad Abdul Wahid**

has successfully presented the paper with the title of

### **Optimizing Electrical Complaints Resolution Through CMMS: A Monte Carlo Simulation Approach**

in 2025 16<sup>th</sup> IEEE Control & System Graduate Research Colloquium (ICSGRC 2025)  
at Mardhiyyah Hotel, Shah Alam, Malaysia  
on 2<sup>nd</sup> of August 2025



PROF. DR. RAMLI ADNAN  
General Chair  
ICSGRC 2025



## APPENDIX XXIII

### 10th International Conference on Marketing and Retailing (INCOMAR)

# Stakeholders<sup>4</sup> Perspectives on Implementing a Computerized Maintenance Management System (CMMS) for Road Electrical Assets

AmarAmjad Bin Abdul Wihii<sup>1</sup>, S. Sarifuh Ritdiah Shariff-, Ih ;i^ MiiMiiLiit-" & Nordiria  
Qayyen RosL<sup>1</sup>

<sup>1</sup> Malaysia Institute of Transport  
i MI LKANSJ, Lnivemti TeknoJogi MARA,  
Shah Alam. 4LW50 Sc-langor. Malaysia  
[amaran/h Jniitlu J'LI sitiJJ.com](mailto:amaran/h Jniitlu J'LI sitiJJ.com)  
[mtrdinarcii@gmaS.com](mailto:mtrdinarcii@gmaS.com)

-Centre for Mathematical Studies, Faculty  
of Computer and Mathematical Studies,  
Univeraiti Teknobgi MARA, 40450, Shah  
Alam, icLanpcr, Malaysia  
[shariQWXQvitm.edu.my](mailto:shariQWXQvitm.edu.my)

<sup>^</sup>Industrial Engineering, University of Muhammadiyah Malang.  
MaLanfj.65144, Indonesia  
[mamtdin\(tL-umm.ac.id](mailto:mamtdin(tL-umm.ac.id)

#### Abstract

Street lighting is a critical road electrical asset that supports visibility, safety, and overall driving performance. When these lighting systems fail to function, the consequences can be severe, ranging from reduced visibility and increased accident risk to heightened vulnerability to crime in poorly lit areas. Despite the importance of these assets, reports and public complaints about malfunctioning streetlights are often not addressed promptly. Delays in responding to these faults not only prolong safety hazards but also highlight gaps in maintenance processes, resource allocation, and real-time monitoring. Persistent issues, such as slow repair turnaround, lack of systematic inspection, and inefficient communication channels, exacerbate the problem and can undermine public trust in road management authorities. Addressing these shortcomings is therefore critical to improving service reliability, ensuring timely intervention, and safeguarding the well-being of road users and surrounding communities. This study examined the operational challenges in Public Work Department's (PWD) road electrical asset management and evaluated the potential contribution of a Computerized Maintenance Management System (CMMS). Data was collected through focus group discussions (FGDs) involving participants across multiple organizational levels. The transcripts were analysed using ATLAS.ti content analysis to identify recurring themes and patterns. The analysis revealed five key thematic factors: System Integration, Needs, CMMS Component Prioritization, Operational Challenges, Desired CMMS Features, and Complaint Management Optimization. Participants consistently highlighted the need for real-time maintenance data, improved coordination, and streamlined complaint handling. Differences in priorities across roles showed that each level had distinct needs that a CMMS could help resolve. Overall, the findings indicate that a well-integrated CMMS is perceived to be able to significantly enhance PWD's maintenance efficiency, resource utilization, and system responsiveness.

Keywords: Road electrical asset management, Computerised Maintenance Management System, implementation and Challenges

# Reverse Logistics for Sustainability and Cost optimization in Palm Oil Industry

Nordina Qajyen Rjosli<sup>1</sup>, S.Sarifah Radiah Sharif<sup>2</sup>, Mahd Rixaimy [Sliaha.ru.duL](mailto:Sliaha.ru.duL)<sup>3</sup>, Amar Amjad Abdul Wahid<sup>1</sup> and Beraardua Yulianto Nugroho<sup>4</sup>

<sup>1</sup> Malaysia Institute at' transport (MITRAKIS), UniVersiti Teknologi MAKA. SuahAlam. 4U4}D Selangor, Malaysia  
[»orditjaro;li^kg}naiti.ccnt](mailto:orditjaro;li^kg}naiti.ccnt)

Centre rbr .Mathematical Studies. faculty of ComjuTe: ai:d Mathsmatical Studies. Luiversrf] lefcno.ogi MAKA. 4U4}0. Hhiu Alam. Sslangor, Malaysia  
[shari99Q@iitim.edu.my](mailto:shari99Q@iitim.edu.my)

<sup>2</sup> Faculty otbusuiEss Management, LniversiofTeknologi MARA Caivangan Jtedah. K ampin SsuEa] i'etam, UK4UU Merbot. iiedan JJaml Aman, Malaysia  
[rE&Dtqj@iitim.edu.B{p](mailto:rE&Dtqj@iitim.edu.B{p)  
<sup>3</sup> Faculty oi Aammistrative yaences, University of Indonesia, Depot, Indonesia 16424  
[ntiEToho.yulianoicr^ihoo.com](mailto:ntiEToho.yulianoicr^ihoo.com)

## Abstract

Reverse logistics plays a vital role in promoting resource recovery, waste reduction, and sustainable operations, yet its implementation is often constrained by industry-specific factors. This study explores the critical factors influencing the implementation of reverse logistics and the challenges faced by the palm oil industry in achieving sustainability. Using a qualitative research design, data were collected through Focus Group Discussions (FGDs) with industry experts from palm oil refineries and logistics divisions to obtain in-depth insights into existing practices and barriers. The data were analyzed using content analysis supported by Atlas.ti software, which enabled systematic coding, categorization, and identification of emerging themes. The findings reveal that geographical location and manpower availability are among the most significant factors impacting reverse logistics implementation, particularly in regions such as Sabah and Sarawak, where transportation and logistical challenges are intensified by terrain and distance. Labor-intensive activities such as loading and unloading further increase operational costs through overtime and workforce demand. The results also indicate that organizations adopt collaborative approaches, such as distributing materials to sister companies instead of reprocessing, to minimize losses and enhance efficiency. Furthermore, the establishment of waste management policies, including the sale of sludge oil and the disposal of outdated machinery, reflects proactive measures to regain opportunities and optimize resources. However, the study identifies major sustainability obstacles, including issues of security and traceability. Especially when engaging with smallholder farmers whose diverse practices and limited monitoring hinder verification and compliance with sustainability standards. Overall, the study emphasizes the importance of strategic collaboration, effective waste management, and enhanced traceability mechanisms to strengthen reverse logistics performance and support the palm oil industry's sustainability agenda.

Keywords: Reverse Logistics, Palm Oil Sustainability, Implementation and Challenges

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**AMAR AMJAD BIN ABDUL WAHID**  
*Stakeholders' Perspectives on Implementing a  
Computenzed Maintenance Management System (CMMS)  
tor Road Electrical Assets*

*in contribution as*

**PRESENTER**

**in the 10th International Conference on Marketing and Retailing  
(INCOMaR) 2025**

*on*

**25th November 2025**

*at*

**Institute of Business Excellence (IBE)  
Universiti Teknologi MARA (UiTM)  
Malaysia**

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DIRECTOR  
of Business Excellence  
Jm.ersa Teknologi MARA, Malaysia



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The 10th International Conference on Marketing and Retailing (INCOMaR)

# Stakeholders' Perspectives on Implementing a Computerized Maintenance Management System (CMMS) for Road Electrical Assets

25 NOVEMBER 2025  
 "Artificial Intelligence and Service Innovation to Drive Business Digital Transformation"


**Authors:**

**Amar Amjad Bin Abdul Wahid**  
 Malaysia Institute of Transport (MITRANS)  
 Universiti Teknologi MARA (UiTM)  
 40450 Shah Alam, Malaysia  
[amaramjadwahid@gmail.com](mailto:amaramjadwahid@gmail.com)

**S. Sarifah Radiah Shariff**  
 Faculty of Computer and Mathematical Science,  
 Universiti Teknologi MARA (UiTM)  
 40450 Shah Alam, Malaysia  
[sharif00@uitm.edu.my](mailto:sharif00@uitm.edu.my)


**Nordina Qayyen Rosli**  
 Malaysia Institute of Transport (MITRANS)  
 Universiti Teknologi MARA (UiTM)  
 40450 Shah Alam, Malaysia  
[nordinarosli@gmail.com](mailto:nordinarosli@gmail.com)

**Nyssa Masudhin**  
 Department of Industrial Engineering  
 University of Muhammadiyah Malang, Malang 65134, Indonesia  
[nyssa@uhumy.ac.id](mailto:nyssa@uhumy.ac.id)



25th NOVEMBER 2025 | 8:30AM-5:00PM  
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The 10th International Conference on Marketing and Retailing (INCOMaR)

# A REVERSE LOGISTICS FOR SUSTAINABILITY & COST OPTIMIZATION IN THE PALM OIL INDUSTRY

25 NOVEMBER 2025  
 "Artificial Intelligence and Service Innovation to Drive Business Digital Transformation"

**Authors:**

**Nordina Qayyen Rosli**  
 Malaysia Institute of Transport (MITRANS),  
 Universiti Teknologi MARA,  
 Shah Alam, 40450 Selangor, Malaysia  
[nordinarosli@gmail.com](mailto:nordinarosli@gmail.com)

**S.Sarifah Radiah Shariff**  
 Centre for Mathematical Studies,  
 Faculty of Computer and Mathematical Studies,  
 Universiti Teknologi MARA,  
 40450, Shah Alam, Selangor, Malaysia

**Mohd Rizaimy Shaharudin**  
 Faculty of Business Management,  
 Universiti Teknologi MARA Cawangan  
 Kedah, Kampus Sungai Petani, 08400  
 Merbok,  
 Kedah Darul Aman, Malaysia.  
[rizaimy@uitm.edu.my](mailto:rizaimy@uitm.edu.my)

**Bernardus Yuliarto Nugroho**  
 Faculty of Administrative Sciences,  
 University of Indonesia, Depok,  
 Indonesia 16424  
[nugroho\\_yuliarto@yahoo.com](mailto:nugroho_yuliarto@yahoo.com)



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25 NOVEMBER 2025  
 "Artificial Intelligence and Service Innovation to Drive Business Digital Transformation"

Collaborator:



## AUTHOR'S PROFILE



Amar Amjad obtained Bachelor of Engineering (Hons) in Electrical Power Engineering (Hons) in 2018 from Universiti Tenaga Nasional (UNITEN), Putrajaya Campus, Kajang Malaysia. He is a postgraduate candidate in Master of Science in Logistic and Transport at Malaysia Institute of Transport (MITRANS), Universiti Teknologi MARA, Shah Alam Campus Malaysia.

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1. Wahid, A. A., & Shariff, S. S. R. (2023, December 20). The features of the unified integrated asset monitoring system for monitoring multiple type of road electrical asset. *In Proceedings of the 5th MITRANS International Logistics and Transport Conference (MILTC2023)*. Petaling Jaya, Malaysia.
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