# A Review of the Current Practices in the Pavement Surface Monitoring in the Philippines

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**Abstract:** Pavement monitoring is the first step in a Pavement Management System (PMS). In the Philippines, the pavement surface monitoring system is handled by the Department of Public Works and Highways (DPWH), and the Local Government Units (LGUs). Two bureaus of the DPWH, namely the Planning Services and the Bureau of Maintenance, are mandated to monitor the defects of the national roads and bridges in the Philippines for different purposes. The DPWH Planning Service (DPWH-PS) is responsible to rate the condition of the national roads, while the DPWH Bureau of Maintenance (DPWH-BoM) monitors the defect on the national road and the urgency of the district engineering offices (DEOs) to repair them. Meanwhile, local roads are monitored by the LGUs, patterned with the procedure done by DPWH. This paper reviews the most recent practices in monitoring road surfaces in the Philippines and other countries. The evaluation methods were compared to identify the gaps between the pavement monitoring system in the Philippines and other countries. Based on the reviewed methods, the researchers identified more advanced monitoring systems from other countries, which led to the recommendation of developing tools and equipment that can enhance the current methodology used to survey the roads in the country; and the inclusion of pavement analysis and maintenance data in the pavement database.

Keywords: pavement management system, pavement surface monitoring system, Philippine roads, pavement condition survey, pavement condition index, pavement database

## 1. Introduction

The Philippine government has recently invested in various transportation structures. Through the “Build! Build! Build!” program, the government is pursuing significant improvement to resolve problems of rapid population growth and urbanization. Building new airports, railways, and roadways in the different regions of the country is part of this program, and more infrastructures are expected to finish in the coming years. Systematic management of these national assets should be done to protect our national investments.

The Pavement Management System (PMS) is a worldwide process employed by different transportation agencies to maintain the serviceable condition of roadways using economical strategies within their jurisdictions. The DPWH employs similar tools to maintain the acceptable condition of road networks in the Philippines. Based on the most recent data of the Road and Bridge Inventory Application (RBIA) of the DPWH, 91% of the roads in the country are paved with asphalt and concrete and as road infrastructure increases, management of these assets can be challenging in the future.

Monitoring of pavement performance varies in different countries. Some countries monitor both the functional and structural performance of the pavement structure and use it as one of the inputs for the prioritization of budget allocation in the system. Functional

performance is being evaluated through the Pavement Condition Index (PCI) and International Roughness Index (IRI). It is based on the collected surface defects of the pavement surface and the comfort of the ride. Structural performance can be evaluated with non-destructive tests or destructive tests. A Falling Weight Deflectometer (FWD) is the most common equipment used for non-destructive testing and coring is the simplest and most common destructive method.
DPWH uses data from functional evaluation as input to the Highway Development and Management Model or well known as HDM-4 (DPWH D.O. No. 234, 2004). This is a software system developed by the World Bank and adopted by different countries like the Philippines to assess the entire road network and help decision-makers in programming the strategic planning of road investments.

In this paper, the current practices in pavement surface monitoring systems in the Philippines will be reviewed. Additionally, specific objectives include the identification of the gaps between the existing systems in the Philippines and other countries, the comparison of the evaluated pavement performance and pavement condition rating locally and internationally, and the recommendation of possible solutions that can bridge the identified gaps. Upon completion of this paper, a summary and review of the current practices in pavement surface monitoring systems in the Philippines will be accessible to other researchers and field experts. Moreover, the gaps in the existing systems in the Philippines and their possible solutions will be emphasized in this paper.

## 2. Pavement Management System

A PMS is defined as a set of procedures that help decision-makers find efficient and cost-effective strategies to maintain pavements in serviceable condition for a specific length of time. The primary functions of PMS are to improve the efficiency of the decision-making process, broaden the scope of pavement management, provide feedback on the consequences of decisions, and guarantee that the decisions made at different levels of the organization are consistent (Haas et al., 1994).

The structure of PMS can be separated into two major levels – network and project levels. At the network level, agency-wide programs for construction, maintenance, and rehabilitation are developed for the entire network such that budgetary resources are used effectively. On the other hand, design, construction, maintenance, and rehabilitation activities are detailed at the project level for the particular road section considered in the project to achieve the targeted service quality at the lowest total cost (Haas et al., 1994; N. Ismail et al., 2009). Figure 1 shows the components of PMS at the network and project levels.

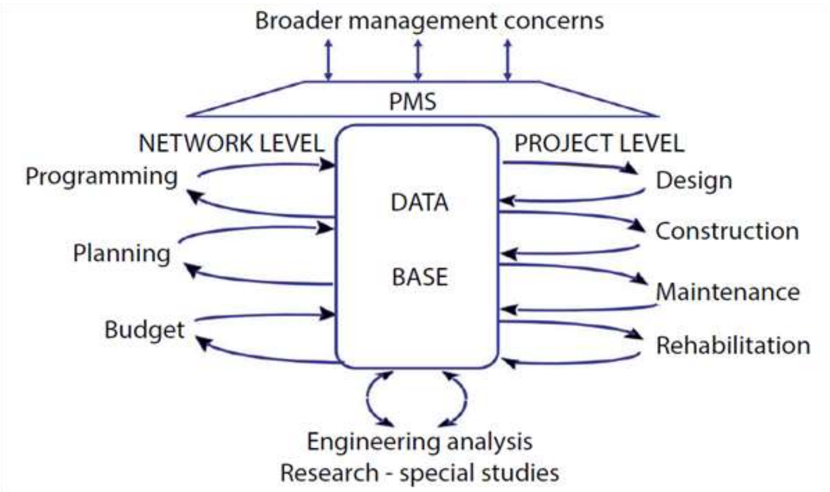


Figure 1. Components of a PMS in Network and Project Levels (Hudson et al., 1994)

## 3. Pavement Monitoring System

To achieve an effective PMS, the first step is pavement monitoring (Chin et al., 2019). In general, pavement monitoring systems allow the acquisition of information on pavement quality and condition. With an effective pavement monitoring system, safety conditions and user satisfaction can be achieved (Baladi et al., 2017; Shtayat et al., 2020).

A complete pavement monitoring system includes three main elements – the embedded sensing device for pavement condition survey, the analysis scheme for post-processing of pavement data, and the database containing information on road condition and maintenance needs (FHWA & AASHTO, 2013). In general, pavement condition surveys refer to the visual inspection that assesses the serviceability and physical condition of the road pavement by measuring the pavement defects (Sharpe et al., 1987). Pavement analysis schemes, on the other hand, aim to assess the performance of a road section based on functional and structural aspects. Functional aspects can be further categorized into two aspects, ride quality or comfort and safety. In general, analysis schemes may come in the form of indices such as the PCI, IRI, Present Serviceability Index (PSI), and Pavement Quality Index (PQI) (AASHTO, 1993; Haas et al., 1994; Marcelino et al., 2018). The last feature is the pavement database which serves as the repository of required information for making decisions regarding maintenance and rehabilitation. For a comprehensive PMS, data needs include section description, performance-related data, historical data, policy-related data, geometry-related data, environment-related data, and cost-related data (Haas, 1991).

## 4. Pavement Monitoring Systems in the Philippines

In the Philippines, roads are classified into these eight categories (PSA, n.d.):

1. National Primary Roads – directly connect to major cities of at least 100,000 people, excluding cities in metropolitan areas
2. National Secondary Roads – directly connect cities (except in metropolitan areas) or major ports and ferry terminals or major airports or tourist service centers to national primary roads; directly connect cities (except major cities); directly connects provincial capitals within the same region; directly connect major national government infrastructures to national primary roads or other national secondary roads
3. National Tertiary Roads – other existing roads under DPWH that perform local functions
4. Provincial Roads (Local Roads) – connect cities and municipalities without traversing national roads; connect national roads to barangays through rural areas; connect to major provincial government infrastructures
5. Municipal and City Roads (Local Roads) – roads within the municipal; roads that connect to provincial and national roads; roads that serve as inter-barangay connections to major municipalities and city infrastructures without traversing provincial roads
6. Barangay Roads (Local Roads) – other public roads that are officially turned over to the barangay and not covered in the above classifications-
7. Expressways – highways with limited access and normally with interchanges and facilities for levying tolls for passage in an open or closed system
8. Bypasses – roads or highways that avoid a built-up area, town, or city to let traffic flow without interference from local traffic

For national roads, current pavement monitoring systems in the Philippines are handled by the DPWH Planning Service (DPWH-PS), and the DPWH Bureau of Maintenance (DPWH-BoM). The DPWH-PS monitors pavement quality based on the Visual Road Condition Assessment Manual (ROCOND) for initial analysis, planning, and budgeting. On the other hand, the DPWH-BoM monitors pavement condition based on their developed "Point System" for their road and bridge and maintenance activities. A pavement monitoring system for the assessment of the pavement condition of local roads was also proposed as a guide for local government units (LGUs).

### 4.1 Pavement Monitoring at Network Level (DPWH D.O. No. 120, 2019)

The ROCOND Manual serves as a guide for measuring, recording, and calculating the rating condition of the road. Based on the DPWH D.O. No. 120, Series of 2019, the road condition survey shall be conducted annually during the first quarter of the year. The DWPH-PS conducts this survey with a team of at least two members together with trained Road and Bridge Information Applications district coordinators. Initially, it was done manually using three different types of visual condition assessment forms. Based on interviews with the planning teams of selected DPWH District Engineering Offices (DEOs), manual ROCOND field surveys are conducted for 2 to 3 months. However, in recent years, DPWH invested in foreign technologies and hired subcontractors from other countries that conduct automated pavement surveys.

The assessment forms during ROCOND field surveys vary depending on the type of road surface (asphalt, concrete, or gravel/earth surface). The assessment forms differ for each road surface since the attributes and defects to be measured and assessed vary depending on the type of road surface. Sample assessment forms can be accessed in the DPWH D.O. No. 120, Series of 2019.

For asphalt road sections, rutting depth, length of edge break, and its corresponding severity, length of patches, number of potholes, base failures, and surface failures, length of wearing surface, and its corresponding severity, and length of cracking and its corresponding severity, are recorded. Other factors such as drains, unsealed shoulder, and sealed shoulder, are also rated based on the corresponding condition.

For concrete roads, the number of shattered slabs is recorded. Other defects considered for concrete pavements are joint faulting, joint spalling, joint sealant, wearing surface, and cracking. Road slip or cuts, drains, unsealed shoulder, sealed shoulder, and vegetation control are also evaluated and recorded.

The third type of assessment form is used for unsealed pavements or roads with gravel or earth surface. For this type of road, the gravel thickness, the material quality, the crown shape, the vegetation control, and the road slip or cut are assessed.

Based on the measured defects, the Visual Condition Index (VCI) is calculated by applying different weight factors to the road defects. The calculated VCI ranges from 0 to 100 and serves as one of the key performance indicators (KPI) used to assess the effectiveness of the asset preservation process. As such, the formula to calculate the VCI should remain unchanged for the analysis of pavement conditions over the years.

The VCI formula also varies depending on the type of road surface (asphalt, concrete, and gravel/earth). The respective weight factors for each defect and the VCI formula for each road surface type are discussed in detail in DPWH D.O. No. 120, Series of 2019. The pavement condition rating can then be identified based on the value of the VCI. Table 1 summarizes the corresponding pavement condition rating given the VCI, and the recommended treatment or rectification measures.

**Table 1. Pavement Condition Rating based on VCI Value and the Corresponding Recommended Rectification Measures (DPWH D.O. No. 120, 2019)**

| VCI Range | Pavement Condition Rating | Recommended Rectification Measures |
|---|---|---|
| 1 – 20 | Bad | Total reconstruction (need to rebuild the pavement) |
| 20.1 – 40 | Poor | Need for extensive and full-depth repairs, and some full slab replacement or rehabilitation |
| 40.1 – 70 | Fair | Preventive maintenance (need for some partial- or full-depth repairs) |
| 70.1 – 100 | Good | Routine maintenance (little to no maintenance required) |

### 4.1.1. Road and Bridge Inventory Application (RBIA)

The data from the ROCOND survey serve as a means of recording the condition of the road network at the time of rating. The survey data are publicly available in the RBIA, the Geographic Information System (GIS) web application of the DPWH. Available pavement data on the said inventory include the road classification, the surface type, the pavement geometry (the carriageway width, the road network shoulders, and the number of lanes), the road condition, and the year of last resurfacing. The data can also be categorized based on location, specifically based on its district and region (DPWH, n.d. -b). Figure 2 shows the condition of the roads in the National Capital Region (NCR), Philippines.

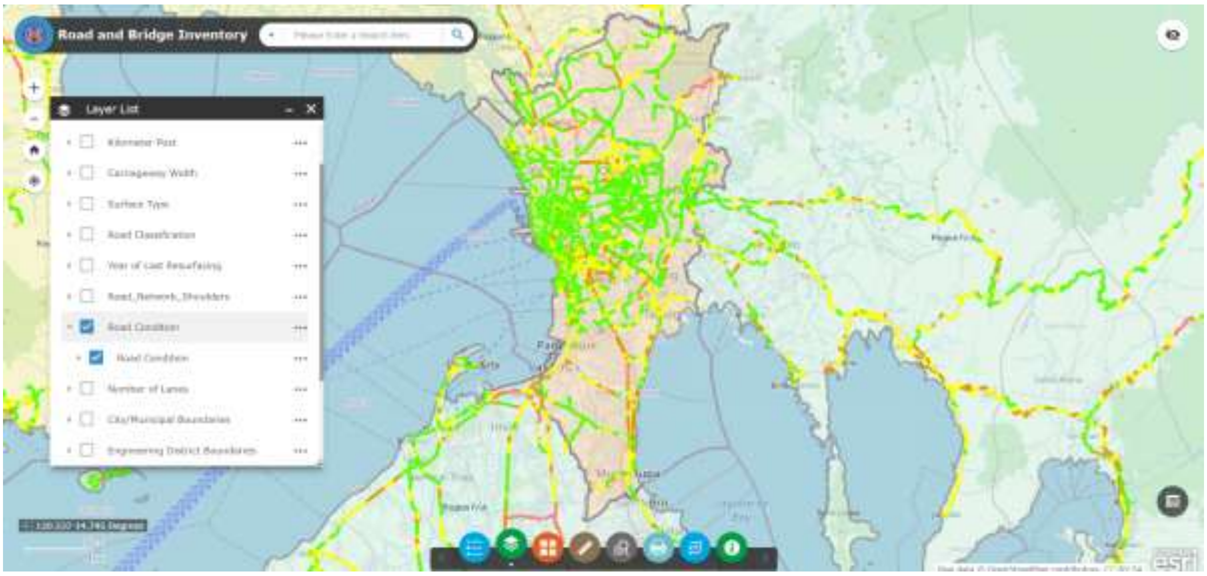


Figure 2. Condition of Roads in NCR, Philippines (DPWH, n.d. -b)

In addition, Road Traffic Information is available to the public as another GIS web application on the DPWH website. Available data include the annual average daily traffic (AADT), traffic survey frequency, and percent heavies (DPWH, n.d. -c). Figure 3 shows the following information for the roads in NCR, Philippines.

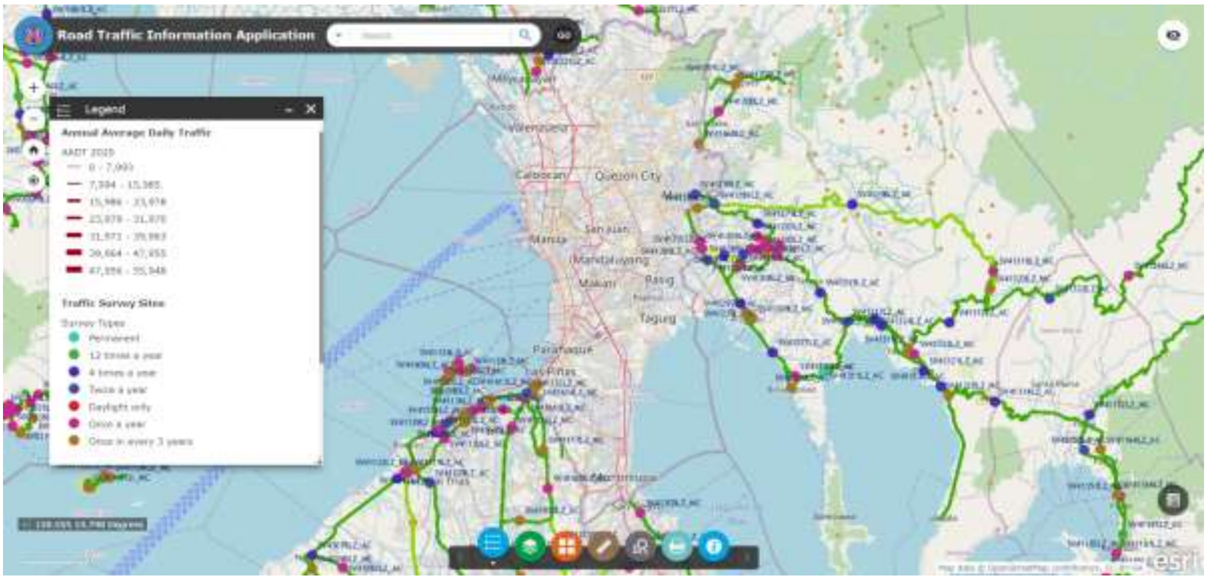


Figure 3. Road Traffic Information in NCR, Philippines (DPWH, n.d. -c)

A Detailed Bridge Inventory is also available on the DPWH website. It contains information on the general bridge type, the bridge geometry (width, structure, height over, height under, number of piers, maximum pier height, number of abutments, and number of spans), the bridge condition, the load limit, the bridge needs ratio, the estimated bridge life, the year of construction, and the year of retrofitting (DPWH, n.d. -a). Figure 4 shows the condition of the bridges in NCR, Philippines.

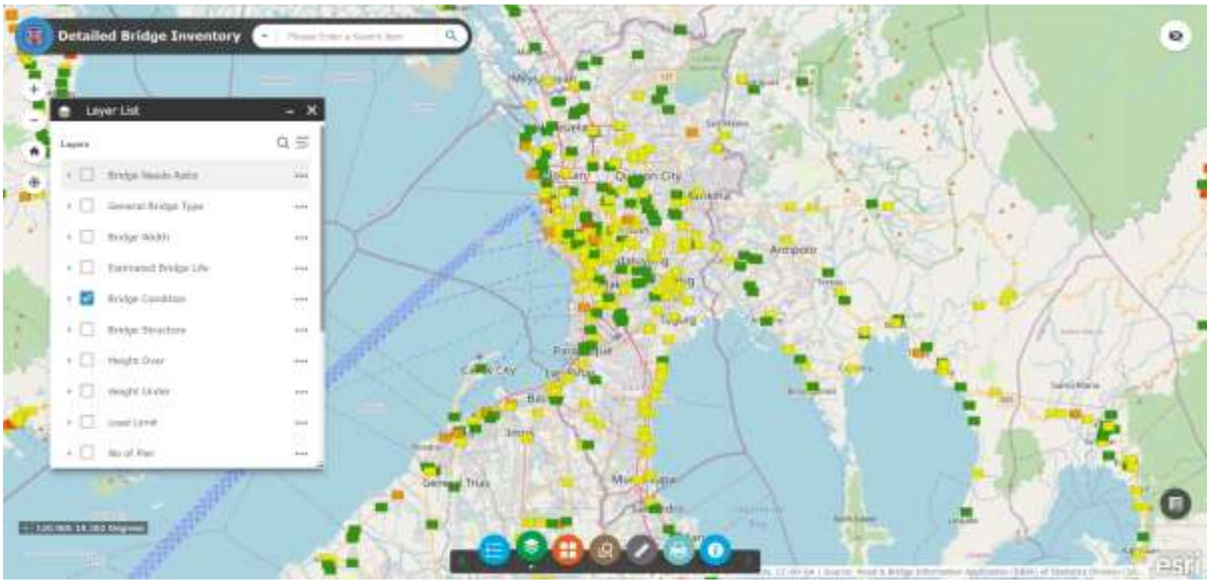


Figure 4. Condition of Bridges in NCR, Philippines (DPWH, n.d. -a)

**4.2. Pavement Monitoring at Project Level (DPWH D.O. No. 41, 2016)**

The pavement monitoring system of the DPWH-BoM is based on the DPWH D.O. No. 41, Series of 2016: “Amended Policy Guidelines on the Maintenance of National Roads and Bridges.” As stipulated in the department order, the DPWH-BoM shall validate the pavement condition assessments conducted by the regional and district engineering offices at least four times a year in areas within the National Capital Region (NCR), and at least twice a year for the rest of the regional offices. The inspection or validation survey has two main purposes: to identify the degree or level of maintenance of the road by measuring the length or area of the defect; and to check the quality and quantity of the completed rectification works based on the noted defects and corresponding response times.

The inspection team shall include one technical personnel from the BoM, accompanied by the District Maintenance Engineer, the Maintenance Point Persons (MPPs), and the Regional Maintenance Division representative(s) assigned in the area. Based on interviews with the maintenance teams of selected DPWH District Engineering Offices (DEOs), manual field surveys are conducted for 1 to 2 days.

During the manual survey, the inspection team records the existence of the 15 defects considered by the DPWH-BoM. Table 2 lists the said defects, and the recommended rectification measures and response times.

**Table 2. Recommended Rectification Measures and Response Times of Road or Bridge Defects (DPWH D.O. No. 41, 2016)**

| Code | Defects | Units | Recommended Rectification Measures | Response Time |
|---|---|---|---|---|
| 01 | Potholes<br>- Bowl-Shaped Depression<br>- Delamination<br>- Slippage Cracking<br>- Edge Break<br>- Spalling<br>- Chuck-Hole or Punch-Out | sq. m. | Hot bituminous premix or penetration patching of the affected area<br><br>On bituminous pavement, the addition of base materials if needed and if no subgrade repair is required | 3 days |
| 02 | Alligator Cracks | sq. m. | Hot bituminous premix or penetration patching of the affected area<br><br>Addition of base materials if needed and if no subgrade repair is required | 3 days |
| 03 | Major Scaling | sq. m. | Re-blocking of slabs | 30 days |
| 04 | Shoving and Corrugation<br>- Shoving<br>- Corrugations<br>- Rutting<br>- Depressions | sq. m. | Half- or full-width replacement of defective pavement<br><br>If a recurrence of the defect occurs in the area, further investigation of the pavement section | 10 days |

| Code | Defects | Units | Recommended Rectification Measures | Response Time |
|---|---|---|---|---|
| 05 | Pumping and Depression | sq. m. | Re-blocking or replacement of concrete pavement<br><br>Base correction | 30 days |
| 06 | No/ Faded Markings | l. m. | Application or re-application of pavement markings using thermoplastic paint | 15 days |
| 07 | Low/Inverted Shoulders<br>- Lane-to Shoulder Drop-off<br>- Uneven Finished Grade Level<br>- Vegetated Shoulder | l. m. | Resurfacing and reshaping of unpaved shoulders<br><br>Reinstatement of dropped or settled shoulders<br><br>Trimming of grasses given that the shoulder is stable<br><br>Provision of a lane-to-shoulder transition for safety purposes | 7 days |
| 08 | Lush Vegetation | l. m. | Vegetation control | 3 days |
| 09 | Clogged Drains | l. m. | Manual cleaning or declogging of drainage culverts, and ditches<br><br>Repair of the damaged lined canal<br><br>Replacement of damaged culvert pieces<br><br>Reshaping of unlined ditches | 3 days |
| 10 | Open Manhole | no. | Repair of damaged drainage manhole covers, opening edges, curb inlets, and drainage grating<br><br>Replacement of missing drainage manhole covers, curb inlets, or drainage gratings | 10 days |
| 11 | No/ Inadequate Sealant Joints | l. m. | Application of sealant on open and undersealed joints | 3 days |

| Code | Defects | Units | Recommended Rectification Measures | Response Time |
|---|---|---|---|---|
| 12 | Cracks<br>- Transverse Crack<br>- Longitudinal Crack<br>- Block Crack<br>- Corner Crack<br>- Diagonal Crack<br>- Meandering Crack<br>- Reflection Cracks | l. m. | Seal working cracks with asphalt sealant or pressurized concrete epoxy<br><br>Consideration of cross-stitching for cracks on concrete | 3 days |
| 13 | Raveling | sq. m. | Removal, replacement, or resealing of the affected road section | 7 days |
| 14 | Unmaintained Road Signages | no. | Repair or replacement of broken or damaged or vandalized signages<br><br>Regular cleaning of signage | 3 days |
| 15 | Unmaintained Bridges | no. | Repair of moderate to severe spalling, scaling and cracking by full or partial depth replacement<br><br>Repair of damaged curbs, sidewalk, wingwall, and railing<br><br>Regular cleaning of the bridge deck and water drain<br><br>Clearing of bridge waterway<br><br>Painting, repainting, or installation of signages and bridge names | 3 days |

Based on the identified defects during the field inspection, the actual response time, and the quality of the rectification works, the DEO in charge of the road section is graded using the “Point System” developed by the DPWH-BoM. Steps for the calculation of the grade in the “Point System” are detailed in the DPWH D.O. No. 41, Series of 2019. Depending on the calculated grade, rewards and sanctions will be given to the assigned officers.

Since the inspection or validation survey is conducted manually, a computerized database of the results of the surveys is not yet available. Pavement data are filed and stored on paper.

### 4.3. Pavement Monitoring System for Local Roads

For the monitoring of local roads, the Department of Interior and Local Government (DILG), with technical support from the United Nations Development Program (UNDP) proposed the "Local Road Asset Management for Local Governments." The manual aims to guide LGUs to use road asset management practices to improve the quality of their respective local road networks (DILG & UNDP, 2019).

Based on the manual, the overall condition of the roads needs to be evaluated using the Local Roads and Bridges Inventory Condition Survey (LBRICS) Guidelines to determine the remaining useful life of the road section. The LBRICS survey is to be conducted annually by the LGUs, preferably during the fourth quarter of the year. It is designed to be conducted by a team of at least five (5) staff and should comprise trained LRBICS personnel (DILG & AusAID, 2014; DILG & UNDP, 2019).

The LBRICS survey is patterned on the DPWH ROCOND survey. Modifications to the ROCOND Manual were made to consider the constraints for LGUs such as limited time, workforce, and financial resources for road condition assessments. Similar to the ROCOND survey, assessment forms vary depending on the type of road surface (asphalt, concrete, or gravel/earth surface), and the VCI is calculated based on the measured defects. From the VCI, the pavement section is rated as either bad, poor, fair, or good using Table 1 (DILG & AusAID, 2014). Specific details of the pavement survey and condition evaluation can be accessed in the LBRICS Guidelines.

## 5. Pavement Monitoring Systems in Other Countries

### 5.1. Pavement Monitoring System in the United States of America (USA) and Canada

Pavement condition surveys in the United States of America (USA) and Canada are conducted by two methods – manual condition surveys, and automated condition surveys. Manual condition surveys are conducted by walking or traveling at a slower speed while noting the existing surface defects. The majority of highways in the USA developed their guidelines or use one of the following methods in conducting field surveys – the Standard Practice for Roads and Parking Lots Pavement Condition Index Surveys (ASTM D6433, 2018), and the Distress Identification Manual for the LTPP (Miller & Bellinger, 2014). On the other hand, automated condition surveys are conducted using specifically designed vehicles to obtain image and profile data in a single pass at posted speeds. Imaging technologies utilized for automated condition surveys include analog, 2D, and 3D systems. (Pierce & Weitzel, 2019).

The pavement data is stored in the database, spreadsheets, TXT format, and native format. Some agencies also store image data in JPEG format. Others use vendor-hosted sites for data storage purposes. Pavement data include images, raw data, condition index, correspondence inventory, and sign inventory (Pierce & Weitzel, 2019).

From the results of the pavement condition survey, pavement performance measures are required to be provided by state highway agencies, as stipulated in Governmental Accounting Standards Board Statement No. 34 (GASB 34). Reports by state highway agencies include the measure, the description of the measure, the latest value of the measure, and the target value (Pierce & Weitzel, 2019). Some of the popular pavement performance measures are PCI, and PSI (Marcelino et al., 2018).

### 5.2. Pavement Monitoring System in Japan

Pavement conditions are monitored in Japan using road surface measuring devices that incorporate laser, light detection, and signal processing technologies. The device quantifies the rutting, cracking, and surface roughness of the pavement section (Kubo, 2017). The pavement performance and the corresponding rehabilitation measures are identified based on the measured rutting, cracking, and surface roughness from the condition survey.

In general, the "Manual for Maintenance and Rehabilitation Roads" issued by the Japan Road Association is implemented for the pavement maintenance and rehabilitation of roads in Japan. In the manual, pavement performance is quantified using the PSI. Depending on the calculated value of the PSI, the repair method, such as surface treatment, overlay, and replacement, is decided. The Ministry of Construction also presented another index called Maintenance Control Index (MCI) based on the pavement data on national roads. For values of MCI equal to 4, pavement rehabilitation is recommended. Another index with a simpler formula, the Tokyo Maintenance Index (TMI), is used in Japan for pavement performance evaluation. For major roads in Tokyo, Japan, the recommended TMI value is 30 (Y. Abe, et al., 1986).

Data on pavement performance, collected from condition surveys and calculated using the indices, are stored in a database. The database includes a display map and service level check for each pavement section (Kubo, 2017). Figure 5 shows the database interface with the display map.

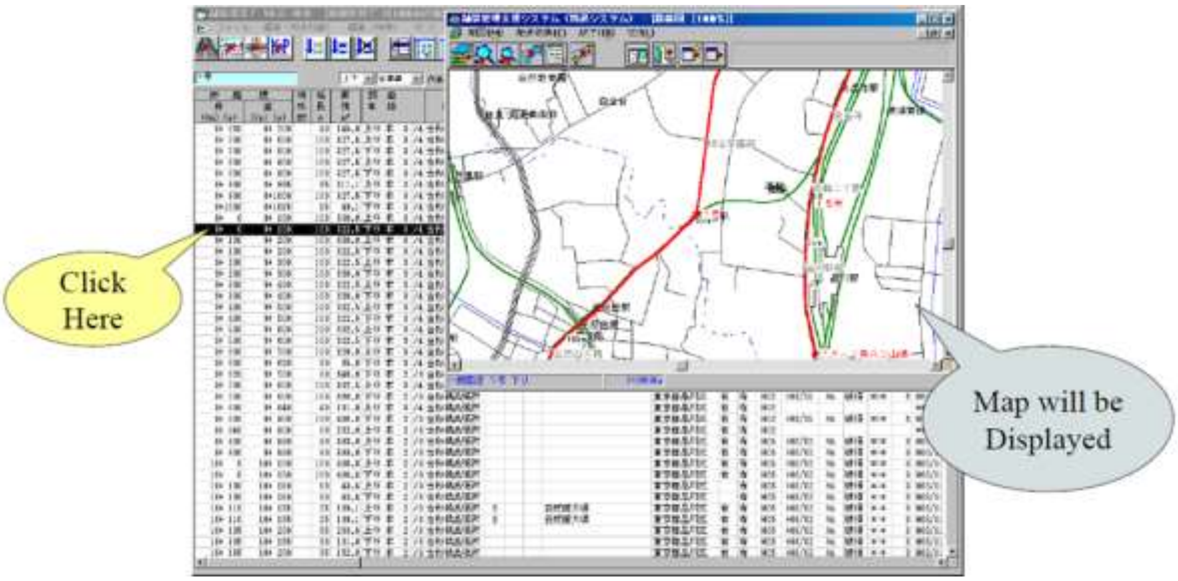


Figure 5. Pavement Database of Japan (Kubo, 2017)

### 5.3. Pavement Monitoring System in South Korea

In South Korea, data on pavement condition, pavement maintenance, and traffic volume are collected at the beginning of each year through field surveys. For their pavement condition surveys, devices such as the FWD and the Ground Penetrating Radar (GPR) are used (Lee & Yoo, 2008).

Defects found common among South Korean roads and given importance in calculating the PCI are rutting, cracking, and roughness. Depending on the type and purpose of the road, the PCI varies. The condition indices in South Korea include the National Highway Pavement Condition Index (NHPCI) for national highways, the Highway Pavement Condition Index (HPCI) for expressways, and the Seoul Pavement Index (SPI) for Seoul city roads. The three indices consider the three defects, rutting, cracking, and roughness, but give different importance to each defect differently by applying varying weight factors (Suh, et al., 2017).

### 5.4. Pavement Monitoring System in United Kingdom Pavement Management System (UKPMS)

The United Kingdom Pavement Management System (UKPMS) is a standard for computer systems that manage and schedule maintenance and rehabilitation activities for pavements through regular condition monitoring. It focuses on pavement data collection, pavement data analysis, maintenance management, and budget allocation. Currently, there are numerous software solutions available that are accredited by UKPMS (AMX Solutions Ltd, 2022; Phillips, 1994).

In UKPMS, pavement data is collected using Coarse Visual Inspection (CVI), Detailed Visual Inspection (DVI), and equipment such as Sideway-force Coefficient Routine Investigation Machine (SCRIM), GripTester, and deflectograph. Pavement data collected from the survey are then stored in a Private Finance Initiative (PFI) database. The PFI database also processes the pavement data and generates condition indices such as the PCI, Surface Condition Index (SCI), and Skidding Resistance Index (SRI) (Wilcox, 2015).

With the collected survey data and calculated indices, the database also includes the recommended maintenance and rehabilitation techniques needed and the detailed design of the work. In general, UKPMS aims to prioritize solutions to problems on pavements rather than the problems (Phillips, 1994).

### 5.5. Proposed PMS for National Freeways in Taiwan

In the research conducted by Lin and Ho (2016), a PMS for freeways was recommended to be established. The system is proposed to be customized for each township and to be composed of at least four subsystems – inquiry, construction and maintenance, conservation indicators, and statistical charts.

The results of the said research can serve as the framework for the development of the PMS for national freeways. In the research, a database was established to simplify and improve the efficiency of managing the national freeway pavements in Taiwan. Specifically, a portal for the “national freeway enter lifecycle management system” was established. The portal contains the data on the basic freeway, the test, the patrol, and the maintenance construction. The skid number (SN) data was also uploaded to the portal. Alongside the mentioned data, users can view the related statistics of the freeway section, including the SN trends, figures, and status description tables (Lin & Ho, 2016). Figure 6 shows the sketch diagram of the described system.


Figure 6. Diagram of Proposed "National Freeway Enter Lifecycle Management System" (Lin & Ho, 2016)

## 6. Comparison of Pavement Monitoring Practices in the Philippines and Other Countries

As the existing pavement ages, distress or defects manifested at the surface are inevitable. Asphalt and concrete pavements have different properties which cause the pavement structure to behave differently. These defects are the basis of calculating the pavement condition rating. Table 3 summarizes the road defects considered in the pavement condition ratings of different countries. From the table, it can be seen that more defects are considered in the pavement index of the Philippines compared to other countries, which can be both an advantage and a disadvantage. By noting and measuring more defects, a better analysis of the pavement condition can be made, and consequently, better maintenance and rehabilitation procedures can be recommended. However, measuring more defects manually can be more time-consuming during field surveys. A possible solution would be to develop and use an automated pavement defect detector.

In addition, it is worth noting that the DPWH BoM "Point System" records defects that occur beyond the pavement, such as unmaintained signages and lush vegetation since the bureau's scope of maintenance works covers the entire national roads' right of way. This ensures that the road is fully serviceable for general public use.

On the other hand, Table 4 summarizes the pavement condition ratings used by the Philippines, the USA, Japan, and South Korea. It can be observed that cracking and rutting are considered in all equations for pavement indices of the countries compared in the table. However, surface roughness is considered in the pavement indices of other countries but not in the "Point System" or the VCI of the Philippines. Since surface roughness is closely related to pavement serviceability (Al-Mansour & Shokri, 2022), further research is recommended to identify if the said factor affects pavement conditions in the Philippines.

**Table 3. Comparison of Road Defects Considered in Pavement Indices of Different Countries**

| Road Defects | Philippines | | USA | | Japan | | | South Korea | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | DPWH-BoM Point System | DPWH-PS VCI | PCI* | PSI | PSI | MCI | TMI | NHPCI | HPCI | SPI |
| | (DPWH D.O. No. 41, 2016) | (DPWH D.O. No. 120, 2019) | (ASTM D6433, 2018) | (Carey & Irick, 1960) | (Abe, et al., 1986; Saitoh & Fukuda, 2000) | | | (Lee, et al., 2009; Suh, et al., 2017) | | |
| Corrugations | O | O | O | | | | | | | |
| Chuck-Hole | O | O | O | | | | | | | |
| Cracking - Crocodile | O | O | O | O | O | O | O | O | O | O |
| Cracking - Longitudinal | O | | O | O | O | O | O | O | O | O |
| Cracking - Transverse | O | O | O | O | O | O | O | O | O | O |
| Cracking - Multiple | O | O | | O | O | O | O | O | O | O |
| Edge Break | O | O | O | | | | | | | |
| Delamination | O | O | | | | | | | | |
| Depression | O | O | O | | | | | | | |
| Faulting | O | O | O | | | | | | | |
| Joint Sealant Deterioration | O | O | O | | | | | | | |
| Patching | | O | O | O | | | | | | |
| Pumping | O | O | O | | | | | | | |
| Potholes | O | O | O | | | | | | | |
| Raveling | O | O | O | | | | | | | |

| **Road Defects** | **Philippines** | | **USA** | | **Japan** | | | **South Korea** | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **DPWH-BoM Point System** | **DPWH-PS VCI** | **PCI*** | **PSI** | **PSI** | **MCI** | **TMI** | **NHPCI** | **HPCI** | **SPI** |
| | (DPWH D.O. No. 41, 2016) | (DPWH D.O. No. 120, 2019) | (ASTM D6433, 2018) | (Carey & Irick, 1960) | (Abe, et al., 1986; Saitoh & Fukuda, 2000) | | | (Lee, et al., 2009; Suh, et al., 2017) | | |
| Rutting (Transverse Evenness) | O | O | O | O | O | O | O | O | O | O |
| Scaling | O | O | O | | | | | | | |
| Shattered Slabs (Slab Cracking) | O | O | O | | | | | | | |
| Shoving | O | O | O | | | | | | | |
| Slippage Cracking | O | O | O | | | | | | | |
| Spalling | O | O | O | | | | | | | |
| Surface Roughness (Longitudinal Evenness) | | | | O | O | O | | O | O | O |
| Clogged Drains | O | | | | | | | | | |
| Low/ Inverted Shoulders | O | | O | | | | | | | |
| Lush Vegetation | O | | | | | | | | | |
| No/ Faded Markings | O | | | | | | | | | |

| Road Defects | Philippines | | USA | | Japan | | | South Korea | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | DPWH-BoM Point System | DPWH-PS VCI | PCI* | PSI | PSI | MCI | TMI | NHPCI | HPCI | SPI |
| | (DPWH D.O. No. 41, 2016) | (DPWH D.O. No. 120, 2019) | (ASTM D6433, 2018) | (Carey & Irick, 1960) | (Abe, et al., 1986; Saitoh & Fukuda, 2000) | | | (Lee, et al., 2009; Suh, et al., 2017) | | |
| Open Manholes | O | | | | | | | | | |
| Unmaintained Road Signages | O | | | | | | | | | |
| Unmaintained Bridges | O | | | | | | | | | |

*The PCI of the USA also includes bleeding, buckling, bumps and sags, durability crack, joint reflection cracking, polished aggregate, railroad crossing, shrinkage, and swelling.

**Table 4. Comparison of Pavement Indices of Different Countries**

| Country | Formula | Parameters |
|---|---|---|
| **Philippines** (DPWH D.O. No.120, 2019) | $VCI_{asphalt/concrete} = MAX(0,(100*(1-(1-((100-((MIN(300,SDWf))/3))*100)^2)^{1/2})))$<br>$VCI_{gravel} = MAX(1,(100-(SDWf-36))$ | VCI = Visual Condition Index<br>SDWf = sum of weighted defects |
| **USA** (ASTM D6433, 2018) | PCI = 100-max CDV | PCI = Pavement Condition Index<br>max CDV = maximum corrected deduct value |
| **USA** (Carey et al., 1960) | $PSI_{asphalt} = 5.03 - 1.91\log(1 + SV) - 1.38(RD)^2 - 0.01(C + P)^{1/2}$<br>$PSI_{concrete} = 5.41 - 1.78\log(1 + SV) - 0.09(C + P)^{1/2}$ | PSI = Present Serviceability Index<br>SV = mean wheel path slope variance<br>RD = mean wheel path rut depth, inches<br>C = cracking, $ft^2$ per 1000 $ft^2$ pavement area<br>P = patching, $ft^2$ per 1000 $ft^2$ pavement area |
| **Japan** (Abe et al., 1986) | $PSI = 4.53 - 0.518\log K - 0.317C^{1/2} - 1.74D^2$ | PSI = Present Serviceability Index<br>MCI = Maintenance Control Index |

| Country | Formula | Parameters |
|---|---|---|
| | $MCI = 10 - 0.47K^{0.2} - 1.48C^{0.3} - 0.29D^{0.7}$<br>$MCI_1 = 10 - 2.23C^{0.3}$<br>$MCI_2 = 10 - 0.54D^{0.7}$ | $MCI_1$ = MCI if cracking is the major factor<br>$MCI_2$ = MCI if rutting is the major factor<br>TMI = Tokyo Maintenance Index<br>K = surface roughness index, cm<br>C = cracked area percentage<br>D = rut depth, cm |
| | $TMI = C + D$ | |
| **South Korea**<br>(Suh et al., 2017) | $NHPCI = (0.33 + 0.003C + 0.004RD + 0.0183IRI)^{-2}$ | NHPCI = National Highway Pavement Condition Index<br>HPCI = Highway Pavement Condition Index<br>SPI = Seoul Pavement Index<br>IRI = International Roughness Index, m/km<br>$SPI_1$ = Crack Index<br>$SPI_2$ = Rut Depth Index<br>$SPI_3$ = Roughness Index<br>C = crack ratio, %<br>RD = rut depth, mm<br>SD = surface distress (crack quantity), $m^2$ |
| | $HPCI_{asphalt} = 5 - 0.54IRI^{0.8} - 0.75RD^{1.2} - 0.9\log(1 + SD)$<br>$HPCI_{concrete} = 5 - 0.80IRI^{0.7} - 0.85\log(1 + 2.5SD)$ | |
| | $SPI = 10 - PDI$<br>$PDI = ((10 - SPI_1)^5 + (10 - SPI_2)^5 + (10 - SPI_3)^5)^{1/5}$<br>$SPI_1 = 10 - 2.23C^{0.3}$<br>$SPI_2 = 10 - 0.2RD$<br>$SPI_3 = 10 - 0.667IRI$ | |

## 7. Discussion

The DPWH-PS and DPWH-BoM originally conducted pavement surface monitoring manually. This means that surveyors are inspecting the pavement surface with the aid of measuring tape and assessment forms. It is the simplest and cheapest method for evaluating road surfaces since it does not require costly equipment. However, this method requires intensive and well-trained manpower. In addition, surveyors are at risk on their job since they are walking the line of the road network together with the traversing vehicles.

**Table 5. Comparison of Duration of Manual and Automated Surveys**

| Type of Road Condition Survey | Agency/Company (Equipment Name) | Approximate Duration (considering 250-km road) |
|---|---|---|
| Manual | DPWH-PS | 2-3 months |
| Automated | Australian Road Research Board (iPAVe) | 1 day |
| | Fugro Roadware (ARAN 9000) | 3 hours |

Aside from problems in manpower and safety, the manual method of pavement data collection is more time-consuming. Table 5 summarizes the comparison of the approximate time to complete a 250-kilometer road considering manual and automated road condition surveys are conducted. Current manual road condition surveys conducted by the DPWH-PS last for 2-3 months to cover an average of 250 km of road sections. The same road length can be assessed by the automated survey equipment developed by the Australian Road Research Board (ARRB) called iPAVe in a day depending on the road composition (ARRB Systems, 2021). Another automated survey equipment called ARAN 9000 can assess the same road length for approximately 3 hours under the assumption that the declared survey speed of 80 kph is achieved (Fugro Roadware, 2013). On the other hand, another international automated survey equipment called RoadAI claims that pavement surface conditions can be accurately assessed four times faster compared to their usual manual road surveys (Vaisala, 2022).

In terms of cost, semi-automated and automated road condition surveys conducted by American agencies range from $30 to $125 per mile or approximately Php 1000 to Php 4300 per kilometer (McGhee, 2004). In comparison, considering labor costs alone, manual road condition surveys conducted by the DPWH-PS cost around Php 4000 per kilometer based on the estimated surveyor count (10 surveyors), survey duration (3 months), survey length (250 km), and labor cost per surveyor (Php 1700 per day).

Aside from manual surveying, DPWH-PS also hired international subcontractors to help them perform automated road surveying. By developing localized automated visual survey equipment, the costs of automated road condition surveys can be reduced significantly.

Developing local equipment could be beneficial for the country not only because of its cost efficiency but also for the digitalization of the pavement database. A reliable database of Philippine pavement conditions can eventually be used to improve the design methodology in the country. Digital records can also communicate the road condition to the citizens. The current GIS web applications also use maps for visualization purposes which are at par when compared to pavement databases of other countries such as Japan (refer to Figure 2 and Figure

5). Web applications may also be advantageous compared to software as the data is available to the general public.

In general, the current pavement database of the Philippines still has room for improvement in terms of storing and visualizing analysis and maintenance data. Unlike the pavement database of Japan, the GIS web application does not provide data on the condition indices. The Philippine pavement database can also include the recommended maintenance and rehabilitation techniques based on the condition indices, similar to the database of the UK.

## 8. Conclusion and Recommendations

In this paper, the current practices in pavement surface monitoring in the Philippines were compiled, presented, and discussed. Particular documents and websites wherein the details of the pavement condition surveys, pavement analysis schemes, and pavement databases of the Philippines were also listed.

The existing pavement surface monitoring system of the Philippines was then compared to the pavement monitoring systems of other countries in terms of pavement condition surveys, pavement analysis schemes, and pavement databases. The difference in the defects considered in pavement condition surveys and pavement indices are also presented in tabular form.

From the comparison, current manual pavement surveying methods were identified as gaps. Hence, using automated survey equipment is recommended to improve the efficiency of the surveying and data collection processes; and to better ensure the safety of the field surveyors. In addition, developing the automated survey equipment locally is recommended as this can be more cost-efficient compared to purchasing international automated survey equipment.

On the other hand, in terms of the pavement data on road traffic information and pavement condition, the current pavement database is comparable to the pavement databases of Japan in terms of interface and data visualization. However, improvements to the pavement database, such as the inclusion of analysis and maintenance data, are still recommended.

The pavement condition surveys and analysis schemes implemented by the country vary depending on the government agency or bureau. Although different offices have different purposes in monitoring the surface condition of the road, consistency in the data collection and data storage processes is still recommended.

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