Doctoral Thesis

Fundamental Study on Improvement of Road and Bridge Management in Laos

ラオスにおける道路・橋梁維持管理の改善に

関する基礎的研究

July 2021

Graduate School of Science and Technology
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SOUMPHONPHAKDY BOUNTHIPPHASERT

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ABSTRACT

Laos is a landlocked developing country located in the heart of the Indochina Peninsular. It shares borders with five other countries (namely China, Myanmar, Thailand, Vietnam and Cambodia). Based on its strategic location, Laos has the potential to transform itself into a land-linked country developing connections with its neighbors through the road network and railways. Thus, development of the transportation infrastructure is one of the most important means of promoting the country's economic development. In the decades since independence in 1975, the Lao Government has invested significantly in infrastructure development, especially expanding and improving the road network. However, looking at the current situation in the developed countries such as the United States and Japan, it is not difficult to imagine that proper maintenance of infrastructure will be a major issues in the future of Laos. Furthermore, based on the experience in the developed countries, it is possible to make future maintenance easier by adopting the improved structure at the time of new construction. Thus, it is necessary for Laos to take actions with an eye on future maintenance from the stage where infrastructure development should be vigorously implemented.

In this dissertation, current situation of road and bridge management and causes of delays in road construction project in Laos are investigated with on-site hearings and collected materials. Then, the bridge management capability of governments across 42 countries receiving development assistance is comprehensively assessed based on reports collected from 102 participants of a training course on bridge maintenance and management prepared by JICA during 2016-2020. The dissertation consists of five chapters as follows:

Chapter 1 gives the background, literature review and objectives of the research. In addition, the layout is given.

Chapter 2, introduces the related administration sectors in Laos, summarizes statistics of data obtained from Laos road (including bridges) sector, and shows the issues in the road and bridge maintenance and management. Such issues are obtained from inquiries from relevant staff, observations and analysis of the actual issues carried out by: the Ministry of Public Works and Transport, the Department of Roads, and the Department of Planning and Cooperation. The main objective of this chapter is to demonstrate and provide basic information about finding solutions.

In Chapter 3, one of the most important sectors in infrastructure development in Laos

is road construction. However, many road construction projects in Laos suffer from extensive delays. This causes damage such as recurring problems in the road construction industry, and has a negative effect on the success of road construction projects in terms of schedule, cost, quality, safety and the amenity of road users. The goal of this study is to determine the main causes of these delays and to offer remedies. To identify the causes of delays, a questionnaire is designed by modifying one used to measure causes of delays in road construction projects in the West Bank in Palestine and in consultation with engineering experts with more than 10 years of experience in Laos road construction projects. A total of 53 causes of delay are identified as important in Laos. Questionnaire respondents included 35 contractors, 31 owners and 24 consultants in total. The survey results indicate that the five top factors causing road construction delays are: Contractor cash flow; Delayed payment by owner; Difficulties in financing project by contractor; Financial issues related to owner; and Insufficient equipment and vehicles for the work.

In Chapter 4, to identify existing issues, the current state of bridge maintenance and management in developing countries is analyzed based on reports collected from participants in training courses on bridge maintenance and management prepared by JICA during 2016-2020. There were 102 participants from 42 countries who participated in the training course. The status of bridge management in these countries has been analyzed considering six major issues: budget-related issues, technical levels, issues of maintenance and management, issues related to bridge maintenance plans, issues related to BMS, and human resource issues. The maturity of the agencies in charge of bridge management in the participating countries is analyzed in each issue area via the introduction of a Transport Asset Management (TAM) maturity scale defined by American Association of State Highway and Transportation Officials (AASHTO). This specifies and compares the maturity levels of the agencies for each TAM process of operating, maintaining, upgrading, and expanding physical assets effectively throughout their life cycle. The analysis revealed the total average maturity to be 2 to 3 on a scale of 1 to 5. Furthermore, on comparing the maturity level of each issue, level in issues of technical level of bridge inspection and level in issues in preparation and implementation of bridge maintenance plan were found to be the lowest, and most of the agencies analyzed were evaluated as 1 or 2.

In chapter 5, the conclusions of the dissertation are summarized, and some measures to be implemented for improving the rod and bridge management in Laos are proposed.

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CHAPTER 1

Introduction

1.1 Background

Laos is a landlocked developing country located in the heart of the Indochina Peninsular. It shares borders with five other countries (namely China, Myanmar, Thailand, Vietnam and Cambodia). Based on its strategic location, Laos has the potential to transform itself into a land-linked country developing connections with its neighbors through the road network and railways. Thus, development of the transportation infrastructure is one of the most important means of promoting the country's economic development. In the decades since independence in 1975, the Lao Government has invested significantly in infrastructure development, especially expanding and improving the road network. However, looking at the current situation in the developed countries such as the United States and Japan, it is not difficult to imagine that proper maintenance of infrastructure will be a major issues in the future of Laos. Furthermore, based on the experience in the developed countries, it is possible to make future maintenance easier by adopting the improved structure at the time of new construction. Thus, it is necessary for Laos to take actions with an eye on future maintenance from the stage where infrastructure development should be vigorously implemented.

Lack of adequate, reliable, and comprehensive information on bridge maintenance and management is a negative factor that hinders the effective development and implementation of appropriate Bridge Management Systems(BMS) in most developing countries. Therefore, one of the purposes of this study is to bridge this knowledge gap and provide practical recommendations to improve the current situation and achieve an appropriately organized bridge management. In this thesis, to identify existing issues by summarizing the current state of bridge maintenance and management in Laos is analyzed. Then the issues encountered in Laos to evaluate the suitability of the methods used for solving and preventing such issues.

1.2 Literature Review

1.2.1 Causes of Delays in Road Construction Projects

Many articles have reported studies on the causes of delay in construction projects. For example, Mahamid et al. [1] found that there are 52 possible causes of delay in road construction projects. Among these, 18 had a severity index of over 60%, indicating a high or very high impact. A.M. Odeh and H.T. Battaomeh [2] used a survey to study the delays arising in construction projects with traditional contracts from the viewpoint of construction contractors and consultants. Results indicated that there was agreement among contractors and consultants that owner interference, inadequate contractor experience, financing and payments, labor productivity, slow decision making, improper

planning, and subcontractors are among the top ten most important factors. Y. Frimpong et al. [3] found that delays and cost overruns are common in construction projects and groundwater development projects in Ghana. Their survey included personnel from owners, consultants and contractors involved in groundwater-related projects. The main causes of delays and cost overruns included difficulty in obtaining monthly payments from agencies; poor contract management; material procurement; poor technical performance; and material price inflation. The study concluded that effective project planning, control and monitoring should be established to enhance project performance in order to minimize or avoid delays and cost problems in groundwater-related projects. J.A. Alsuliman [4] investigated the causes of delays in Saudi public construction projects and categorized them based on the various stages of a project, namely (1) factors before the award of tenders, (2) factors during the award of tenders, (3) factors after the award of tenders, and (4) general factors. Through the use of a focus group, this study identified 50 delay factors. A questionnaire was administered and distributed to 211 people involved in the construction industry. From the results, the top 20 causes of delay were identified. A final simplified formula was developed to calculate the effect of each cause of delay on site. A case study was carried out to determine the percent time delay compared with the master schedule using the developed simplified formula. Banobi E.T.B. and W. Jung [5] investigated 82 owner-side experts and 106 contractor-side experts in Tanzanian power construction projects. In successful projects (less than 10%-time delay), the owners and contractors gave weight to similar causes, including vandalism and permits from authorities. Both suggested similar mitigation strategies such as close supervision, capacity building training, and proper logistics management. On the other hand, in the case of unsuccessful projects (more than 10%-time delay), they exhibited many different responses. In particular, contractors gave more weight than contractors to causes such as changes in scope, poor supervision by the owner, delays in approval, planning failures, and design risks. Owners on the other hand gave more weight to mitigation strategies such as top management support and timely procurement. R.F. Aziz and A.A. Abdel-Hakam [6] investigated strategies to effectively overcome road construction delays in developing countries, concluding with suggestions for fundamental and large-scale reform of procurement systems and stakeholder management. Khatib, B.A., Poh, Y.S. and El-Shafie [7] conducted fourteen interviews with project managers, construction managers, and senior site engineers to identify the factors they faced that led to delays in a reconstruction project. The identified factors were divided into two groups: one related to the demolition phase (five factors) and the second related to reconstruction work (nine factors). The supply of building materials during the reconstruction phase was considered one of the major delaying factors and 14 delay factors were identified that should be carefully considered to assure the sustainability of the main objective during reconstruction activities. A. Orangi et al. [8] found that delays could lead to some serious

time and/or cost overrun issues, thereby adversely affecting contractors, clients and other stakeholders to different degrees. They concluded that consolidating knowledge from related research and lessons from recent projects would be beneficial for rationalized project management. In particular, identifying significant root causes of delays and then developing suitable management methods (e.g. prevention measures) are essential to effectively ensuring successful project outcomes.

M.H. Fallahnejad [9] set out to identify and rank the causes of delays in gas pipeline projects in Iran. 24 completed gas pipeline projects were studied and the extracted delay factors were discussed with 10 experts from several disciplines. The result was a 43-item list of factors, which were then ranked by means of a questionnaire survey. The 10 major delay factors were found to be the following: imported materials, unrealistic project timescale, client-related materials, land expropriation, change orders, contractor selection methods, payments to contractor, obtaining permits, suppliers, and contractor's cash flow". Majed Alxara et al. [10] studied the issues faced by Saudi Arabia in completing construction projects on time and on budget. It has been documented that 70% of public construction projects are delayed in the country. A case study was performed at a university campus in northern Saudi Arabia, identifying the major causes of project delays. The university had experienced delays ranging from 50% to 150%. The study proposed solutions for minimizing the nine major delay factors. A literature research identified one construction management method, the Performance Information Procurement System (PIPS), that has been documented multiple times to improve project performance and minimize delays. B.-G. Hwang et al. [11] looked at reducing wait times for future public housing owners, which requires such projects to be completed on time. A survey of 36 industry experts revealed that "site management", "coordination among various parties", and "availability of laborers on site" were the top three factors affecting the schedule performance of public housing projects in Singapore. In findings from a case study, Raj Shah [12] clarified that the most influential factors in Australia are (1) planning and scheduling deficiencies, (2) methods of construction, (3) effective monitoring and feedback processes, which contrasts with Ghana where they were (1) delays in payment certificates (2) underestimating of project cost, (3) project complexity. On the other hand, in Malaysia the most influential factors are (1) improper planning by contractors, (2) poor site management, and (3) inadequate contractor experience. It is clear that the factors causing project delays and cost overruns are diverse and vary from one country to another. N.D. Long et al. [13] presented problems with large construction projects in Vietnam. Data analysis revealed that the problems could be grouped under five major headings: (1) incompetent designers/contractors, (2) poor estimation and change management, (3) social and technological issues, (4) site related issues, and (5) improper techniques and tools. Michał Głuszak and Agnieszka Leśniak [14] carried out a survey and multivariate statistical analysis of client's ideas about construction delays in Poland. They found that

timely implementation of construction work (at the scheduled time) is vital for both the investor and the contractor. Even perfectly planned and organized projects run the risk of delays. Despite many tools supporting construction management, delays keep occurring in construction projects. S.O. Ogun Lana et al. [15] took the view that construction industry problems in developing economies can be nested in three layers: (a) problems of shortages or inadequacies in industry infrastructure (mainly supply of resources); (b) problems caused by clients and consultants and (c) problems caused by contractor incompetence/inadequacies.

1.2.2 Assessment of Bridge Management Capability

As more countries recognize the importance of infrastructure in supporting socio-economic development, infrastructure maintenance, and repair issues, particularly road and bridge maintenance, have gained increasing attention. By definition, bridge maintenance and management are activities that allocate resources to maintain and support the existing operation of bridges (Hurt and Schrock, 2016, p. 291) [16].

Road networks are the most critical elements of infrastructure systems, and bridges are the primary connecting points. If bridges deteriorate because of aging, fatigue, loading, weather conditions, natural disasters, or other reasons, the repair work would be more expensive than maintenance work. Thus, bridge management is considered important for the planning and prioritization of maintenance and repair. Currently, one of the most critical problems in bridge management is related to its destruction (Maxwell, 1990; cited in Amiri et al., 2018) [17]. Many previous studies have been investigated till date in the field of bridge repair and maintenance (Lee and Kim, 2007[18]; Xiao et al., 2010[19]; Orcesi and Frangopol, 2011[20]; Yin et al., 2011[21]; Stemberk and da Silva, 2013[22]; Gholami et al., 2013[23]; Barone et al., 2014[24]; Saviotti, 2014[25]; Hu et al., 2015[26]; Wu et al., 2017[27]; Xie et al., 2018[28]). Jeong et al. (2018) [29] conducted a cross-country study on bridge inspection and management programs in four countries (China, Japan, Korea, and the US) to identify lessons for these countries and put into effect in improving bridge inspection procedures and maintenance in their countries.

1.3 Objective and Layout of the Dissertation

The main objective of this dissertation, current situation of road and bridge management and causes of delays in road construction project in Laos are investigated with on-site hearings and collected materials. Then, the bridge management capability of governments across 42 countries receiving development assistance is comprehensively assessed based on reports collected from 102 participants of a training course on bridge maintenance and management prepared by JICA during 2016-2020. The dissertation

consists of five chapters as follows:

Chapter 1 gives the background and objectives of the research. In addition, the layout is provided.

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In Chapter 3, the main causes of the delays in road (including bridge) construction projects in Laos are identified. This chapter's study was conducted using a questionnaire; 53 causes of delay are identified as necessary in Laos. Atotal 90 persons responded to the Questionnaire including 35 contractors, 31 owners, and 24 consultants. The survey results indicate that the five top factors causing road construction delays are: Delays in contractor cash flow; Delayed payment by the owner; Difficulties in financing projects by the contractor; Financial issues related to the owner; and Insufficient equipment and vehicles for the work.

In Chapter 4, to identify existing issues, the current state of bridge maintenance and management in developing countries is analyzed based on reports collected from participants in training courses on bridge maintenance and management prepared by JICA during 2016-2020. There were 102 participants from 42 countries who participated in the training course. The status of bridge management in these countries has been analyzed considering six major issues: budget-related issues, technical levels, issues of maintenance and management, issues related to bridge maintenance plans, issues related to BMS, and human resource issues. The maturity of the agencies in charge of bridge management in the participating countries is analyzed in each issue area via the introduction of a Transport Asset Management (TAM) maturity scale defined by American Association of State Highway and Transportation Officials (AASHTO). This specifies and compares the maturity levels of the agencies for each TAM process of operating, maintaining, upgrading, and expanding physical assets effectively throughout their life cycle. The analysis revealed the total average maturity to be 2 to 3 on a scale of 1 to 5. Furthermore, on comparing the maturity level of each issue, level in issues of technical level of bridge inspection and level in issues in preparation and implementation of bridge maintenance plan were found to be the lowest, and most of the agencies analyzed were evaluated as 1 or 2.

Finally, in Chapter 5, the main conclusions of the dissertation are summarized.

The layout of the dissertation is given in Fig. 1.1.

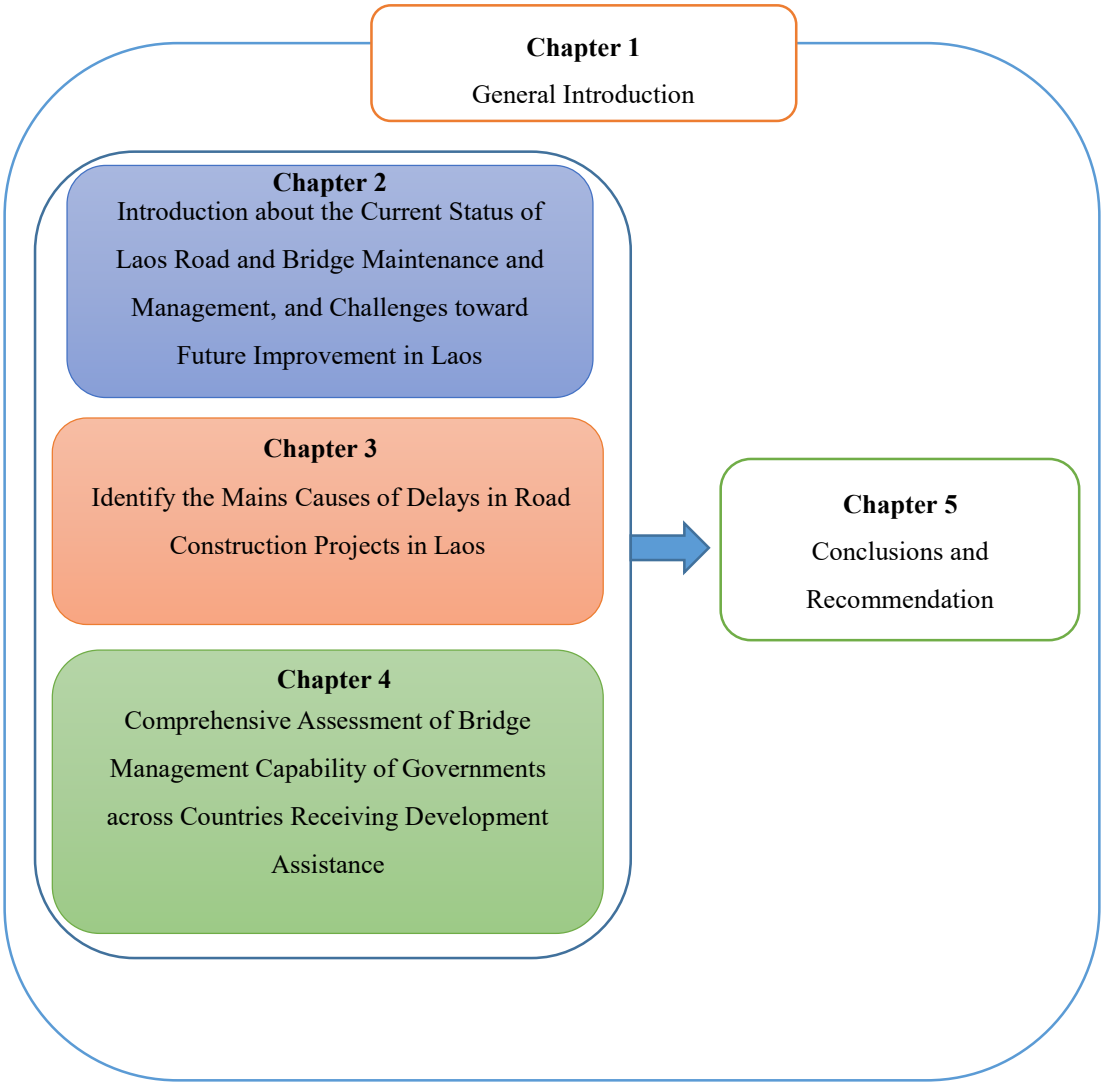

Fig. 1.1 Layout of the Dissertation

CHAPTER 2

Current Status of Road Maintenance and Management in Laos and Challenges toward Future Improvement

2.1 Introduction

Since its independence in 1975, the Laotian government has invested significantly in infrastructure development, especially with respect to the expansion and improvement of road networks.

Laos is a developing country located in the heart of the Indochina Peninsula and shares borders with five countries a 423 km border with China in the north, 2,130 km of border with Vietnam in the east, 541 km of border with Cambodia in the south, 1,754 of border with Thailand in the west, and a 235 km border with Myanmar in the northwest making Laos a land-locked country. However, based on its strategic location, Laos has the potential to transform itself into a land-linked country by networking its roadways with the neighboring countries.

To guarantee the safety and comfort of the road users, it is necessary to expand the road network, build bridges and ensure effective maintenance of the constructs. This alleviates road problems and ensures that the roads are always in good condition, which in turn guarantees road safety at minimal cost. With limited budget and a long-standing problem of road management systems in Laos, it is necessary to find the best way to solve these issues and achieve maximum benefit and highest efficiency.

In the road sector, Laos government has received technical and financial support from many donors and agencies to achieve overall sustainable road management by improving planning, prioritization, sector financing allocation, management, maintenance efficiency, and climate resilience of the roads. However, multiple obstacles were encountered in starting such projects as information regarding the current status of road maintenance management in Laos is not publicly listed, and there is no proper catalogue of the data files and related documents. Therefore, the main objectives of this study are as follows:

- To provide the necessary basic information and the latest statistics regarding the road network in Laos;
- To explain the current status of road maintenance management; and
- To summarize some of the issues in the road sector and the necessary measures for its improvement.

2.2 Road Management Overview

2.2.1 Management Organization

The Lao road network is classified into six classes: (1) national roads (NR), (2) provincial roads (PR), (3) district roads (DR), (4) urban roads (UR), (5) rural roads (RR), and (6) special roads (SR). In terms of road management, the Ministry of Public Works

and Transport (: MPWT), through its Department of Roads (: DOR), is responsible for the maintenance of the national road network (7,700.57 km) [30]. In the provinces, there are 18 departments of public works and sports (DPWT), and every DPWT responds to the maintenance of local roads, including PR (8,657.41 km), DR (7,174.70 km), and UR (4,032.64 km). Urban development authority agencies manage RR (25,234.28 km). SR (5,454.88 km) is not under the jurisdiction of MPWT or DPMT, but would typically fall under other ministries or private enterprises. Every DPWT's are not only depending on MPWT, they are also directly dependent on Provincial Governors. Therefore, there are several additional steps involved in the road management process. And the main road manager in Laos road networks is the Department of Roads (DOR) is only depending on MPWT.

The implemented unified road maintenance framework demarcates roles among each stakeholder in road maintenance programming and planning such as Road Maintenance Fund (: RMF), Urban Development and Administration Authority (: UDAA) including the integration of the departments involved, namely Public Works and Transport Institute (PTI), DOR, and DPWT. In the Unified Road Maintenance Framework Center, we have PTI that acts as a facilitator for the road maintenance management cycle, and also as a center for the analysis of the completed plans and programs. This also means that PTI is the responsible unit for the road management systems as well as systematic data collection on roads and bridges. These works were transferred back to the DOR in 2017.

The RMF provides the maintenance funds for national roads and provincial budgets, including maintenance funds for the local roads. Even if the donor's fund includes a significant contribution to the maintenance budgets, Donor's funding is provided through the RMF, a more direct funding plan.

2.2.2 Road Management System (RMS)

The RMS program was developed for the MPWT. The system was originally developed under the Road Maintenance Program 1, which was supported by the Nordic Development Fund and the World Bank since 2001. However, the enhanced Road Maintenance Program 2 was supported only by the World Bank. RMS is a tool for road network administration in Laos. It assists in various divisions and planning levels within the DOR in strategic planning, programming, prioritizing roads requiring maintenance and rehabilitation, contracting, monitoring, and evaluation.

After the road inventory and location referencing for RMS was established in 2001, the RMS was established in February 2003 by MPWT and DPWT's and international consultants. After the establishment, the RMS was tested by running the system by MPWT in November 2003.

Several management systems have been adopted to support activities under the Unified

Road Maintenance Framework. This primarily includes the usage of RMS for the national roads and provincial road maintenance management system (PRoMMS) for local roads.

From 2007 to 2009, this project improved the link between RMS and PRoMMS and provided a strong and sustainable system operation capacity. Since 2014, a technical cooperation project in road maintenance, which was conducted by Japan International Cooperation Agency (: JICA), had focused on improving data collection by using tablets, providing link to integrated road asset management system, and integrating an intelligent monitoring system [31, 32] for evaluating road roughness with International Roughness Index (: IRI). The RMS Framework [33] is shown in Fig. 2.1.

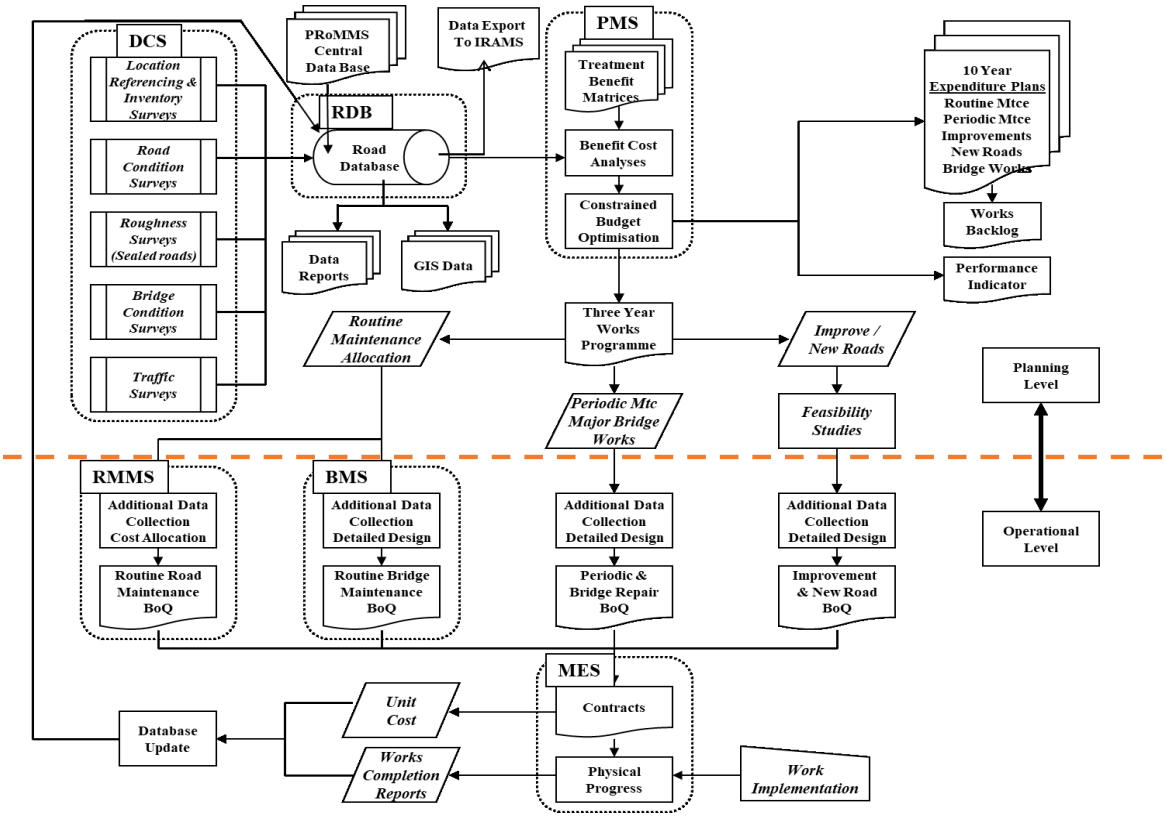

Fig. 2.1 Road Management System (RMS) Framework [33]

The RMS comprises a road information database, data collection system, road data bank, and traffic monitoring system, providing a repository for the inventory and data management for all types of roads in Laos (except special roads). The system also comprises the Pavement Maintenance System, which analyses the maintenance and rehabilitation needs for roads and optimizes them under the given budget constraints. The Pavement Management System which is utilizing the HDM-4 (highway development and management series, a guide to calibration and adaptation, Vol. 5, 2000) as the analysis engine, provides multi-year programs (e.g., three years) and strategic expenditure plans over 10 years. The RMS is also used to analyze the maintenance needs for the entire road network and sub-networks, which is called the Routine Maintenance Management

System (: RMMS), to provide inputs to the programming and planning tasks under the unified road maintenance framework. The RMS can upload the data in the PRoMMS database to ensure that the RMS database stores information within all road networks. Thus, RMS is linked to a geographical information system (GIS) that shows a variety of data (collected data or analysis output) on maps. GPS referencing is currently available only for national roads and information.

To guarantee the safety and convenience of road users, it is necessary to expand road networks and construct bridges and ensure proper maintenance of those constructs. This solves the road problem and ensures proper condition of roads, which in turn guarantees the safety of the roads with minimal cost. In particular, bridge maintenance management works require higher attention compared to road maintenance management works; the reason is that although road damage causes significant inconvenience to the road users, any damage to a bridge leads to loss of life and property. If a bridge breaks down, there will be a disruption in traffic, and the cost of construction of a new bridge and subsequent maintenance of the same requires a big budget. This includes the time for the road construction, the time required to import the facilities from abroad, and skilled human resources experienced in surveying and designing for the construction, renovation, and maintenance.

Hence, MPWT has to focus on bridge maintenance management. The bridge maintenance system (BMS) comprises several analysis modules; it analyses the conditions of the bridge, plans for the maintenance and rehabilitation needed for the bridges, and prioritizes them as per the budget constraints.

2.3 Stock of Road Network

2.3.1 Classification of Roads and Total Length of the Road Network

The total length of road network reported in the year 2019 was 58,254.48 km [30], a decrease of about 2,085.73 km comparing the statistic year 2018 [34] as shown in Table 2.1. For the year 2019, we have 7,700.57 km of national roads, 8,657.41 km of province roads, 7,174.70 km of district roads, 4,032.64 km of urban roads, 25,234.28 km of rural roads and special roads of about 5,454.88 km.

Graphical distribution of the share of each road class is provided in Fig. 2.2 [30]. The rural road network covers 43.32% of the total road length. While the national road network shares only 13.22% of total roads length, and provincial road network is 14.86%, the district road network is 12.32%, the urban road network is 6.92% and the special road network is 9.36% of the total length, as shown in Table 2.2[30], which shows all road network lengths in Laos by road classes, provinces, and pavements.

Table 2.1 Classification of Roads and Total Length of the Road Network, the year 2018 and 2019 [30, 34]

Classification	Road Length [km]		Different [km]
	2018	2019	
National	7,524.16	7,700.57	176.41
Province	8,482.74	8,657.41	174.67
District	7,144.32	7,174.70	30.38
Urban	3,695.90	4,032.64	336.74
Rural	26,219.85	25,234.28	985.57
Special	7,273.24	5,454.88	-1,818.36
Total	60,340.21	58,254.48	-2,085.73

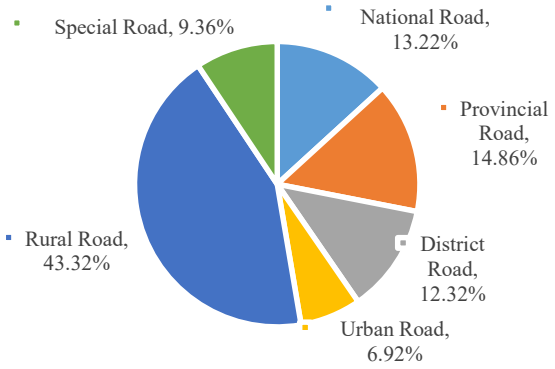

Fig. 2.2 The proportion of road network by classification

Table 2.2 Road Length by Road Classes and Provinces

Pro. Code	Province's name	Road Length (Km) by Road Classes						Total
		National	Provincial	District	Urban	Rural	Special	(km)
1	Vientiane Capital	243.05	288.75	471.96	917.04	705.51	113.88	2740.19
2	Phongsali	474	773.95	673.1	93.727	1,350.26	1007.04	4372.075
3	Louangnamtha	311.68	480.326	109	104.908	1034.541	179.61	2220.065
4	Oudomxai	326.5	293.85	624.182	149.246	1,445.20	920.845	3759.823
5	Bokeo	162.4	273.35	150.3	86.993	589.22	42.475	1304.738
6	Louangphabang	605.2	564.05	358.221	238.683	2,397.03	1011.4	5174.584
7	Xaignabouli	445	740.32	961.8	165.304	1673.36	21.5	4007.284
8	Houaphan	527.1	864.815	511.21	355.241	818.15	227.50	3304.018
9	Xiengkhouang	436	469.92	65.84	79.221	2,299.38	197.295	3547.654
10	Vientiane	405.73	595.521	604.12	376.267	816.862	252.652	3051.152
11	Bolikhamxai	534.85	518.1	358.9	144.991	766.42	66	2389.261
12	Khammouan	592.97	322.166	379.1	223.416	2,188.07	99.16	3804.877
13	Savannakhet	765	739.16	599.595	344.464	3,278.75	12	5738.969
14	Salavan	533.5	184.1	257.76	151.311	2,311.34	194	3632.013
15	Champasak	208.23	329.7	258.51	88.201	912.67	235.66	2032.971
16	Xekong	442.4	733.55	466.286	216.474	1,796.45	664.35	4319.505
17	Attapeu	355.46	192.83	58.1	168.7	659.56	66.2	1500.85
18	Xaysomboun	331.5	292.95	266.72	128.451	191.512	143.316	1354.449
Total		**7,700.57**	**8,657.41**	**7,174.70**	**4,032.64**	**25,234.28**	**5,454.88**	**58,254.48**

The road network condition can be rated as excellent, good, fair, poor, bad, or fail. In terms of maintenance, roads in excellent and good condition require only the routine

maintenance. However, special attention is required for the loads in fair condition.

Fig. 2.3 shows the rating share of all the road networks in Laos; roads in excellent and good condition constitute approximately 40.80% of the total roads, whereas roads in fair condition constitute approximately 21.48% [35]. However, poor, bad, and failed conditions constitute approximately 38% of the total road network length

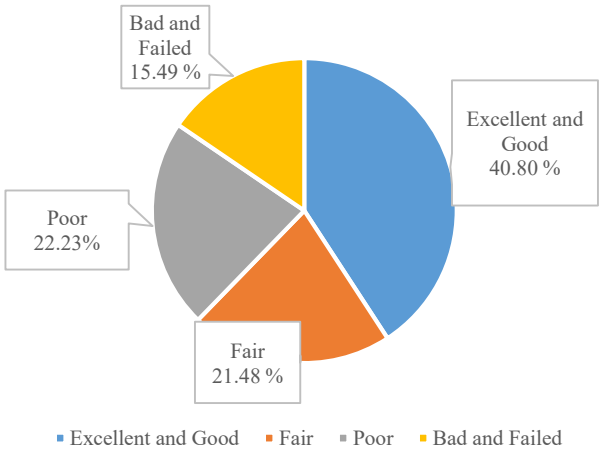

Fig. 2.3 The proportion of condition of the entire road network based on visual inspection

Table 2.3 show the statistics year 2019 of road network length by road classification and provinces source from Departmant of Roads.

2.3.2 Number of Bridges

Bridge management systems (BMS) are also included in the RMS. Most of the BMS database of bridges does not specify the exact year of construction, maintenance or rehabilitation. The BMS was used only for the bridge maintenance and repairs. It uses the data from the annual bridge condition surveys, assigns priorities to bridge elements for maintenance/repair works, prioritizes works as per the constrained budgets, and produces a bill of quantities for the cost incurred towards the maintenance activities to prepare the bid documents. The number of bridges corresponding to the road type in the Laos road network is shown in Table 2.4 [35].

Table 2.3 Road network length by road classification and provinces (Department of Roads Summary of Road Network Statistics 2019)

Pro. Code		01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	
Province's name		Vientiane Capital.	Phongsali	Louangnamtha	Oudomxai	Bokeo	Louangphabang	Houaphan	Xaignabouli	Xiengkhouang	Vientiane	Bolikhamxai	Khammouan	Savannakhet	Salavan	Champasak	Xekong	Attapeu	Xaisomboun	Total
National roads (1)	Concrete	19.40	5.80	0.00	0.00	40.70	0.00	0.00	0.00	0.00	8.69	0.00	4.37	0.00	0.00	0.00	13.48	0.00	0.00	**92.43**
	Asphalt conrect	103.25	4.00	159.28	123.50	94.70	36.62	0.00	38.10	0.00	1.50	6.25	0.00	242.00	2.13	3.40	71.40	114.90	0.00	**1,001.03**
	Paved	120.40	442.20	101.30	203.00	27.00	568.58	445.00	489.00	388.40	359.34	475.60	441.30	306.50	363.87	191.83	327.53	84.56	181.50	**5,516.91**
	Gravel	0.00	22.00	51.10	0.00	0.00	0.00	0.00	0.00	47.60	36.20	53.00	122.52	93.00	157.50	13.00	30.00	47.73	150.00	**823.65**
	Earth	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	24.78	123.50	10.00	0.00	0.00	108.27	0.00	**266.55**
	Total	243.05	474.00	311.68	326.50	162.40	605.20	445.00	527.10	436.00	405.73	534.85	592.97	765.00	533.50	208.23	442.40	355.46	331.50	**7,700.57**
Provincial roads (2)	Concrete	75.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.20	0.00	0.00	3.10	0.00	0.00	6.20	0.50	0.00	**91.53**
	Asphalt conrect	5.30	0.00	0.00	0.00	0.00	0.00	0.00	28.00	0.00	0.00	0.00		0.00	0.00	0.00	31.40	0.00	0.00	**64.70**
	Paved	128.22	11.00	11.77	5.25	44.71	159.39	350.00	292.24	163.57	114.32	130.20	61.17	187.34	110.00	7.00	137.77	25.77	127.70	**2,067.41**
	Gravel	79.70	398.35	344.06	288.60	180.04	404.66	390.32	276.22	268.75	374.70	193.80	231.81	469.78	74.10	322.70	436.40	166.56	143.75	**5,044.29**
	Earth	0.00	364.60	124.50	0.00	48.60	0.00	0.00	268.36	37.60	100.30	194.10	29.19	78.95	0.00	0.00	121.78	0.00	21.50	**1,389.48**
	Total	288.75	773.95	480.33	293.85	273.35	564.05	740.32	864.82	469.92	595.52	518.10	322.17	739.16	184.10	329.70	733.55	192.83	292.95	**8,657.41**
District roads (3)	Concrete	57.14	0.00	0.00	0.00	0.00	0.36	0.00	0.17	0.00	0.00	0.00	6.19	0.00	0.50	0.00	3.46	0.00	0.00	**67.83**
	Asphalt conrect	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-
	Paved	143.38	3.60	0.00	12.39	22.50	22.64	37.50	29.46	50.44	150.05	5.50	21.30	59.02	8.00	12.15	89.27	1.00	52.20	**720.39**
	Gravel	261.44	430.00	17.00	510.49	71.30	235.09	551.70	236.82	15.40	288.40	205.40	261.70	345.48	225.48	207.76	320.91	57.10	197.48	**4,438.95**
	Earth	10.00	239.50	92.00	101.30	56.50	100.13	372.60	244.76	0.00	165.67	148.00	89.91	195.10	23.78	38.60	52.65	0.00	17.04	**1,947.54**
	Total	471.96	673.10	109.00	624.18	150.30	358.22	961.80	511.21	65.84	604.12	358.90	379.10	599.60	257.76	258.51	466.29	58.10	266.72	**7,174.70**
Urban roads (4)	Concrete	172.48	4.54	0.00	0.00	6.15	3.26	0.00	2.13	0.00	3.40	9.30	25.28	37.55	0.00	0.00	17.22	0.00	11.67	**292.98**
	Asphalt conrect	58.58	0.00	0.30	12.60	16.54	15.01	0.00	12.82	0.00	0.00	0.00	0.00	14.53	0.00	3.80	0.00	0.00	0.00	**134.17**
	Paved	196.12	22.91	41.86	61.04	17.06	69.10	106.85	174.02	53.24	67.47	62.34	77.28	127.86	35.56	47.42	72.34	71.99	36.73	**1,341.19**
	Gravel	354.34	27.32	23.91	53.14	26.02	80.65	51.25	69.62	18.30	181.31	59.84	106.70	98.51	66.69	13.74	77.77	70.44	77.56	**1,457.11**
	Earth	135.52	38.96	38.84	22.47	21.23	70.67	7.20	96.65	7.68	124.09	13.51	14.15	66.01	49.06	23.24	49.15	26.27	2.49	**807.18**
	Total	917.04	93.73	104.91	149.25	86.99	238.68	165.30	355.24	79.22	376.27	144.99	223.42	344.46	151.31	88.20	216.47	168.70	128.45	**4,032.64**
Rural roads (5)	Concrete	12.11	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.00	12.00	2.90	2.21	15.36	0.33	0.00	1.85	0.00	0.00	**46.93**
	Asphalt conrect	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**4.00**
	Paved	47.06	2.00	4.26	7.50	1.60	43.53	58.80	55.14	72.20	90.93	9.49	93.87	61.95	39.37	12.20	79.94	44.44	32.00	**756.28**
	Gravel	426.41	286.93	188.13	680.35	226.33	557.08	447.80	393.80	1377.96	447.35	373.53	1133.13	2115.64	785.38	255.79	619.91	475.32	87.11	**10,877.94**
	Earth	219.93	1061.33	842.15	757.35	361.29	1796.25	1166.76	365.21	849.22	266.58	380.50	958.86	1085.80	1486.27	644.68	1094.76	139.80	72.40	**13,549.13**
	Total	705.51	1350.26	1034.54	1445.20	589.22	2397.03	1673.36	818.15	2299.38	816.86	766.42	2188.07	3278.75	2311.34	912.67	1796.45	659.56	191.51	**25,234.28**
Special roads (6)	Concrete	4.23	2.00	0.00	0.00	0.38	0.30	2.00	2.19	0.00	0.00	27.00	0.46	5.00	0.00	0.00	14.15	0.00	0.00	**57.71**
	Asphalt conrect	0.00	0.00	0.10	9.00	0.00	0.00	0.00	2.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**11.53**
	Paved	19.50	2.00	1.77	28.34	6.03	2.50	0.00	31.82	34.40	44.52	25.50	15.13	0.00	24.10	29.00	25.60	19.00	41.00	**350.20**
	Gravel	68.05	52.62	15.24	69.00	13.20	273.85	8.00	37.05	99.20	121.47	10.00	70.99	7.00	24.00	173.36	112.40	9.70	69.62	**1,234.75**
	Earth	22.10	950.42	162.50	814.51	22.87	734.75	11.50	154.01	63.70	86.66	3.50	12.58	0.00	145.90	33.30	512.20	37.50	32.70	**3,800.69**
	Total	113.88	1007.04	179.61	920.85	42.48	1011.40	21.50	227.50	197.30	252.65	66.00	99.16	12.00	194.00	235.66	664.35	66.20	143.32	**5,454.88**
Total Length of Roads in the Province	Concrete	340.89	12.34	0.00	0.00	47.23	4.09	2.00	4.50	0.00	30.29	39.20	38.51	61.01	0.84	0.00	56.35	0.50	11.67	**649.40**
	Asphalt conrect	167.13	4.00	159.68	145.10	111.24	51.63	0.00	85.35	0.00	1.50	6.25	0.00	256.53	2.13	7.20	102.80	114.90	0.00	**1,215.43**
	Paved	654.68	483.71	160.95	317.52	118.90	865.74	998.15	1071.67	762.25	826.64	708.63	710.06	742.66	580.90	299.60	732.44	246.76	471.13	**10,752.38**
	Gravel	1189.94	1217.22	639.44	1601.58	516.89	1551.33	1449.07	1013.51	1827.21	1449.43	895.57	1926.84	3129.41	1333.15	986.35	1597.38	826.85	725.52	**23,876.69**
	Earth	387.55	2654.81	1259.99	1695.63	510.49	2701.80	1558.06	1128.99	958.20	743.30	739.61	1129.47	1549.36	1715.00	739.82	1830.53	311.84	146.13	**21,760.57**
	Total	2740.19	4372.08	2220.07	3759.82	1304.74	5174.58	4007.28	3304.02	3547.65	3051.15	2389.26	3804.88	5738.97	3632.01	2032.97	4319.51	1500.85	1354.45	**58,254.48**

Table 2.4 Proportion of bridge type by road classification

Bridges Type	National	Provincial	District	Urban	Rural	Special	Total
Concrete Slab	105	6	23	0	6	0	140
Concrete T-Beam, In Situ	76	91	27	4	12	0	210
Concrete T-Beam, Precast	386	0	0	0	0	0	386
Concrete Box ,Girder	22	0	0	0	0	0	22
Steel Girders, Concrete	25	13	5	0	8	0	51
Steel Truss, Bailey	96	116	48	2	66	0	328
Half through, Steel	10	0	0	0	0	0	10
Through Steel ,Truss	1	0	0	0	0	0	1
Deck Type ,Steel	6	3	3	2	10	0	24
Timber Beam	76	103	132	0	297	0	608
Log	5	0	0	0	0	0	5
Arch	50	0	0	0	0	0	50
Cable Stayed	1	0	0	0	0	0	1
Box Culvert	467	198	78	5	89	0	837
Wet Crossing	16	0	0	0	0	0	16
Other (Specify)	19	33	47	1	22	4	126
Total	1361	563	363	14	510	4	2815
Percentage by Road classes (%)	48.35	20.00	12.90	0.50	18.12	0.14	100

2.4. Budget for Road Sector

2.4.1 Sources

The budget for road maintenance management operation has three sources of funding. First, (1) the Laotian government annual budget for road maintenance management framed every year; this fund comes from oil charges, oil tax, transit fee, vehicle annual fee, cross over bridge fee, auction of the license plate, penalties for violators and regulations, contributions of both domestic and international jurists, and other appropriate income. Second, (2) low-interest-rate loans from foreign countries and agencies whose interest rate is not over 2% per year; this type of funding has a unique process, wherein the MPWT submits the proposal to the MPI, after which the MPI coordinates with the Ministry of Finance to submit the annual investment budget of Laos for the approval from the government. Third, (3) donations from foreign countries and using the cooperation of other organizations. Since Laos has requested aid from foreign countries and international aid agencies, many countries and international agencies such as JICA (Japan), World Bank, Asia Development Bank, Nordic Development Fund, etc., have provided financial and technical assistance to further develop MPWT institutional capacity for the future implementation of the road sector.

2.4.2 Statistic of Annual Investment on Road Sector

The statistics of annual investment in the road and bridge replacement/upgrading cost, new construction cost and repair cost from the year 2004 to 2018, excluding investment in railways, are listed in Table 2.5 [36]. Fig. 2.4 [36] shows a comparison of the budget investment by the proportion of replacement/upgrading cost, new construction cost and repair cost. The budget investment in the Laos road sector consists of the Laotian government's annual budget (domestic funds) and foreign funds (grant aid from foreign countries and/or organizations cooperation, and partially budgeted by low-interest rate loans from foreign countries and/or organizations). Table 2.6 [36] shows the budget from domestic funds and foreign funds invested in on-road management in Laos from 2004 to 2018.

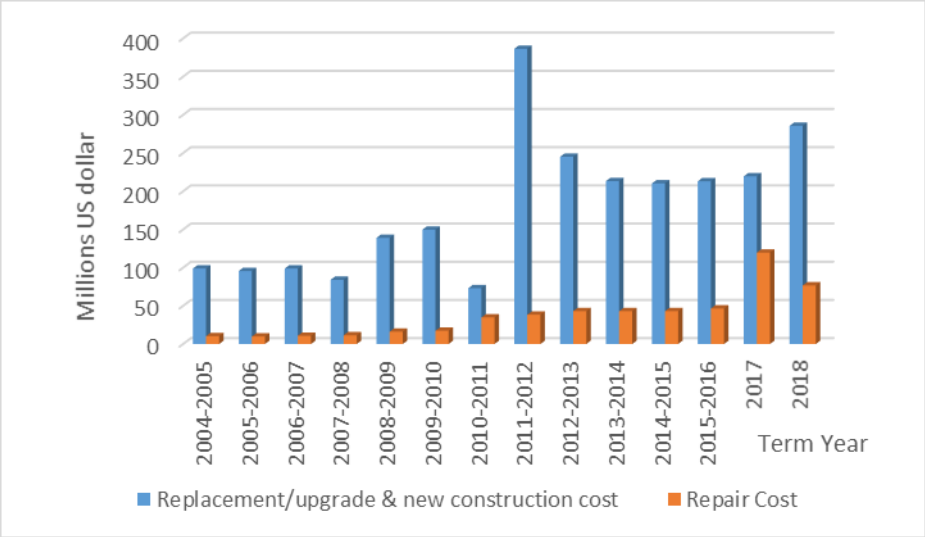

Fig. 2.4 Budget proportion of replacement/upgrading cost, new construction cost, and repair cost

The Laos government allocated a proportion of the annual budget for RMF, under a decree on road maintenance fund No. 130/Gov [10]. This is designed to ensure a sufficient and stable domestic source of revenue for road maintenance. Under the decree, RMF annual revenue is allocated to road maintenance works on national and local roads, wherein 90% was allocated for national roads, 80% for bridges, 20% for local roads (provincial, district, and commodity roads), 5.3% for new construction for all road networks, 0.2% for roads in Vientiane Capital, 2.5% for safety works program for the national roads, and 2% for management works. The details of the proportion of the annual budget for road maintenance management in Laos are shown in Table 2.7 and Fig. 2.5.

Table 2.5 Statistic of annual budget investment in road sector

Year	Replacement / upgrading cost & new construction cost (Million USD)	Repair cost (Million USD)	Total (Million USD)
2004-2005	98.88	10.28	109.16
2005-2006	95.59	9.82	105.42
2006-2007	98.82	10.80	109.62
2007-2008	84.09	11.46	95.54
2008-2009	139.07	16.12	155.19
2009-2010	149.66	17.44	167.10
2010-2011	73.12	34.88	108.01
2011-2012	386.52	38.37	424.89
2012-2013	245.20	43.02	288.22
2013-2014	213.34	43.02	256.37
2014-2015	210.40	43.02	253.42
2015-2016	213.16	46.51	259.68
2017	219.59	119.73	339.33
2018	285.73	76.74	362.47

(Exchange rate calculation 1US dollar = 8600 kips)

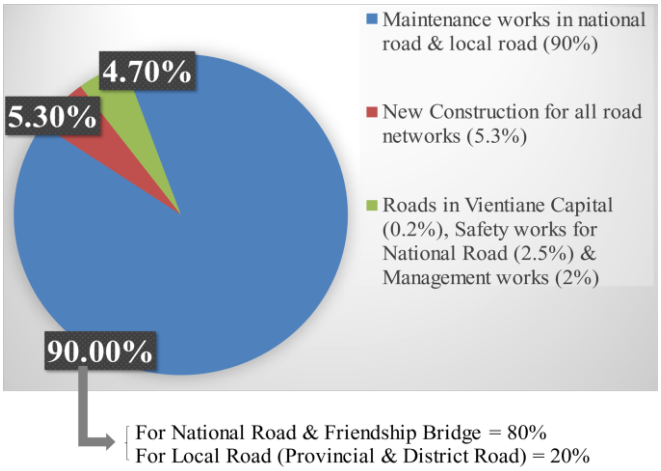

Fig. 2.5 The proportion of annual budget for RMF

Table 2.6 Budget from domestic fund and foreign funds invested on road and bridge management in Laos from 2004 to 2018 [Million USD]

Year	Domestic	Foreign	Total
2004-2005	8.14	101.02	109.16
2005-2006	13.75	106.76	105.42
2006-2007	14.19	107.01	109.62
2007-2008	17.67	77.88	95.54
2008-2009	22.23	132.97	155.19
2009-2010	28.52	138.58	167.10
2010-2011	43.97	64.04	108.01
2011-2012	55.04	369.85	424.89
2012-2013	68.84	226.71	288.22
2013-2014	60.78	195.59	256.37
2014-2015	60.70	192.73	253.42
2015-2016	66.40	193.28	259.68
2017	153.15	186.17	339.33
2018	150.88	211.59	362.47

(Exchange rate calculation 1US dollar = 8600 kips)

Table 2.7 The proportion of annual budget RMF for road and bridge maintenance and management

The proportion of Annual Budget for Road Network	Percentage
Maintenance works in national road & local road	90.00 %
New Construction for all road networks	5.30 %
Roads in Vientiane Capital (0.2%), Safety works for National Road (2.5%) and Management works (2%)	4.70 %

2.5 Issues to be resolved

2.5.1 Road Management System

RMS assists road management activities from planning through implementation in the

entire country of Laos. RMS programs have seen long term developments, making it quite effective. However, there are still multiple weak points in the process that needs improvement. The issues of RMS are as follows: (1) lack of continuity due to lack of accountability, further, there is a lack of focus on the development of human resources responsible for RMS work; (2) budget allocation not being based on RMS prioritization because of the ambiguous regulations that are not officially recognized and the failure to update the database of road conditions in RMS; (3) lack of funds to operate RMS because of the complete reliance on foreign countries and/or organizations for funding. Hence, the Laotian government has not invested in RMS at all.

2.5.2 Road Statistics

The statistics of road network databases in Laos were collected from DOR, using RMS. The different points of the two parts were the DOR statistics collected by recording from the road length of every project for national roads and other road classes recorded from the DPWT. On the other hand, as per the RMS database collected by survey teams from PTI (until 2016) and survey teams from DPWTs, the budget for the survey was insufficient. Therefore, the RMS database was not able to cover all the locations in the Laos road network. Thus, the total missing road length between data storage in RMS and official data from the DOR is approximately 50%. A significant difference is seen in the special roads and urban roads. For national roads, two data sources are slightly different; the RMS database misses just about 10% of the data compared to the official statistics. The statistics of the two databases are shown in Table 2.8 [35].

Table 2.8 The statistics of road in 2016 by road classification

Class	Road length (km)		Road length missing in RMS	
	RMS	DOR	[km]	[%]
National	7,019	7,730.96	711.96	10.14
Provincial	6,731	8,205.42	1,474.42	21.90
District	5,690	6,919.21	1,229.21	21.60
Urban	718	3,063.18	2,345.18	326.63
Rural	17,227	24,883.78	7,656.78	44.45
Special	166	5,529.24	5,363.24	3230.87
Total	37,551	56,331	18,780	50.01

2.5.3 Design Standard

As per the technical manual of road design of 1996, the road sector received technical assistance to improve the standard for road design from JICA in the project named “The Project for Improvement of Road Management Capability in Lao PDR” in Lao PDR " conjunction with ADB grant aid. Therefore, on August 20, 2018, Laos’s road sector started to use the new, improved version of the design manual [37].

However, the new improved vision of road manual design is not as good as it should be. The new update in the current version does not contain the design to use fly ash material with cement in bridge construction. Because the construction of the bridge incurs a huge cost, the presence of a higher number of cement industries in Laos compared to steel industries can cut down cost, making it the primary reason why most of the bridge constructions in Laos have focused on the use of concrete structures.

There are three reasons why fly ash should be used in conjunction with cement: (1) Till the end of 2015, in Hongsa district, Xayabury province of Laos, power plants use coal for power generation. The fly ash remains after their processing can be used with the concrete mixture, as has tested and experimentally confirmed by the University Khon Kaen, Thailand. They found that the fly ash can be used in the concrete mixture at a rate of approximately 15% to 20% [38, 39] to make them stronger and more durable. This idea is also confirmed by other foreign countries. (2) The waste can be recycled, which benefits the ecology and the environment. (3) The bridge structure can be used for a longer period reducing the budget for bridge repair and reconstruction.

Moreover, the construction and repair of bridges are costly and time-consuming. At the same time, highly experienced and specialized personnel are required to perform such tasks. As a result, many developed countries have improved designs to make the bridges more durable and easier to maintain and repair. However, improvements in road manual design have not yet been specified. Presently, the Lao road sector focuses on building bridges using concrete instead of the existing bridges in the country, which are old steel bridges with a composition of at least 30% (Timber Beam, Steel Truss, and Bailey), as shown in Table 2.9 [35]. Hence, the future bridge foundations will be made of concrete. For these reasons, there is an urgent need to use fly ash as a cement mixture to ensure long-term durability and savings in future maintenance costs.

Table 2.9 The statistics of bridges by bridge type

Types of Bridges	Number of Bridges	Percentage (%)
Concrete Slap	881	31.30%
Steel Truss, Bailey	363	12.90%
Timber Beam	608	21.60%
Box Culvert	837	29.73%
Other(specify)	126	4.48%
Total	2,815	100.00%

2.5.4 Budget

The infrastructure development of Laos has led to economic growth of the country. Presently, the Laos government has given priority to the construction of national roads, to ease traffic and facilitate heavy trucks to move with ease. ASEAN Highway (AH) routes passing through the national road of Laos with eight lines (AH 3, AH 11, AH 12, AH 13, AH 15, AH 16, AH 131, and AH 132), is shown in Fig. 2.5 [40].

All AH routes passing through national roads must be upgraded to the AH standards, as stipulated in the contract. According to the decree on road fund No. 130/Gov [37], the proportion of the annual budget for the road fund in Laos is shown in Fig. 2.5. As shown in the figure, the national road constitutes only 13.22% of the total length of all roads across the country.

In addition, the present proportion of the annual budget for the local road for each province, did not allocate the shares based on road condition, road length, or RMS because of insufficient data. Therefore, the share value for all local roads is divided into 18 provinces across the country and each province is allocated with equal budgets. Thus, this is one of the main reasons for roads in some provinces or some routes in bad or failed conditions.

2.5.5 Road Authorities

There are many problems with the allocation of responsible personnel for various tasks. Sometimes there will not be sufficient officers for work, because of the rotation in work-shift. As a result, the work takes intermittent breaks or delays because it is not possible to find the right people with the right qualifications for the job. Therefore, the problem mentioned above concerns the technical knowledge transfer, training systems, and technical specifications of road maintenance management work.

2.5.6 Unit Price of Road Construction

The unit price of road construction is one of the main problems. Therefore, the unit price of road construction has been updated since 2012. MPWT was used until 2019, and the unit price set was the only one that was used as the unit price of road construction throughout the country, without precisely dividing the country into regions (or not dividing as appropriate), and nothing was updated until 2019. In addition, the unit price updated in 2012 on the list of items in the road construction sector in Laos was still insufficient. As of 05/09/2019, MPWT has revised it again according to agreement No. 21901/PWT [41], which is considered a major update divided into three regions: northern, central, and southern regions. It also improved the list of items in the road construction sector.

However, the unit price that was updated is the cash price after the work is completed. The payment to the contractor shall not exceed 90 days from the date of inspection to hand over. Disbursements have not been made as scheduled, as can be seen in authors' study on causes of delays in road construction projects in Laos [42], which is the second cause of delay at 81.56%. Apart from the issues mentioned above, there are still many issues that can be seen in the study [42].

2.5.7 Information disclosure

Issues regarding information on agreements, road manual design and technical requirements, unit prices, and decrees in the road sector are not disclosed to the public, such as through notices on the Ministry's website, newspapers, offline or online. However, in fact, the documents of decrees, terms, and agreements can be disclosed to the public and the relevant departments to be recognized in order to comply with the agreements, techniques, and regulations that have already been set, and for all parties to recognize and comply with the documents in a unified manner.

In addition to the issues mentioned above, there are also have other issues such as material quality.

2.6 Conclusion

RMS is an effective system. However, there is insufficient budget to implement it in Laos, and MPWT does not pay much attention to RMS. This indicates that no budget

accounts for RMS, making it difficult to implement RMS. The annual budget for the roads allocated by the Laotian government cannot meet the demand, and national roads and bridges are in the list of priorities. The proportion of the annual budget for the local road in each province is not commensurate with road conditions, road length, or RMS. This is because there is no exact road information for all road networks in Laos. Thus, there is an inappropriate budget allocation. However, there is a budget for the LRSP project, which has recently received financial support from international organizations to strengthen maintenance systems and to improve reliable road connectivity in Laos. The DOR statistic and RMS statistics do not match according to the plan of the ongoing LRSP2 project. The project also included all road network data survey collections by using a new updated software of RMS. The DOR statistic was used in the same database. Road manual design and technology were updated in 2018. Laotian government organizations are also included in the road sector because there are many problems with the allocation of personnel responsible for various tasks. Sometimes, there are not enough officers for work, which results in frequent changes in the position of responsibility. As a result, government organizations have problems with intermittent work or delays. It is hence important to find the right people with the right qualifications for the job. Thus, for the above-mentioned problems, technical knowledge transfer, training systems, and technical specifications of road maintenance management work should find a solution. Although the unit price of road construction has been improved, it is seen that the related disbursements are also redefined in the bidding process to be more detailed. Therefore, it affects the unit price due to the lack of disclosure of relevant agreements, the road design manual and technical requirements, unit prices, and decrees in the road sector. Consequently, the situation makes it difficult for parties involved in maintenance and management to be recognized and fail to comply.

CHAPTER 3

Causes of Delays in Road Construction Projects in Laos

3.1 Introduction

Laos is a landlocked developing country located in the heart of the Indochina Peninsular. It shares borders with five other countries (namely China, Myanmar, Thailand, Vietnam and Cambodia). Based on its strategic location, Laos has the potential to transform itself into a land-linked country developing connections with its neighbors through the road network and railways. Thus, development of the transportation infrastructure is one of the most important means of promoting the country's economic development. In the decades since independence in 1975, the Lao Government has invested significantly in infrastructure development, especially expanding and improving the road network.

The total length of the road network in Laos is over 60,340 km, including 552 km of reinforced concrete (RC) roads, 1,203 km of asphalt concrete (AC), 9,973 km of double bituminous surface treatment (DBST), 23,179 km of gravel and 25,433 km non-paved. There is still a lack of annual budgets for road maintenance, rehabilitation and upgrading to ensure standards and improved road safety.

As in many countries, road construction projects often fall behind schedule in Laos. In fact, 36 of 59 ongoing projects in January 2020 had been behind schedule. This is an important issue affecting the management of road construction projects. There is a need to study the main causes of such delays and search for solutions that improve the situation. Delays in road construction have many negative impacts, such as budget over-runs and effects on the economy, the environment and other areas. They particularly affect those who use the roads and/or live near roads under construction, both directly and indirectly. The causes of road construction delays vary by country. Thus, it is important to determine the main common causes of delay in road construction projects in Laos.

In this study, a questionnaire survey was carried out. The questionnaire was designed by modifying one used to measure causes of delays in road construction projects in the West Bank in Palestine [1] and in consultation with engineering experts with more than 10 years of experience in Laos road construction projects, and sent to contractors, owners and consultants.

The main objectives of this study are the following:

- To identify the causes of delays in road construction projects in Laos;
- To rank the causes of delays in road construction projects in Laos;
- To identify the severity of delay causes from the perspective of contractors, owners and consultants;
- To test agreement on the ranking of the severity of delay causes among contractors, owners and consultants;
- To find ways to eliminate the causes of delays in road construction projects in

Laos;

- To provide this research data to owners, consultants, contractors and designers for use in preparing and planning road construction; and
- To provide knowledge for engineers and the general public interested in the analysis of factors that cause problems due to delays in road construction projects in Laos.

3.2 Research Methodology

3.2.1 Questionnaire Design

In this paper, based on work in the literature [1], a questionnaire was developed in consultation with civil engineers who had more than 10 years of experience in road construction projects in Laos. Final modifications were made to accommodate the whole range of information about effective causes of delay in road construction projects in Laos. A total of 53 possible causes were included in the questionnaire.

In terms of structure, the questionnaire was designed to have two main parts. Part I is related to respondents' personal information, including whether they are contractors, owners or consultants. It includes questions pertaining to their experience in the construction industry. Part II includes the list of the identified causes of delay in road construction projects in Laos. These causes are classified into eight main groups as shown in Table 3.1 according to the source of delay: project, owner, contractor, consultant, design, laborers, materials and equipment, and external. For each cause a question was asked about its degree of severity in terms of contributing to project delay. Severity was categorized into six-levels as follows: level 0 = no influence; level 1 = very low; level 2 = low; level 3 = moderate; level 4 = high; and level 5 = very high.

Table 3.1 List of Possible Delay Causes and Groupings

Main group	Causes under each group	
1. Project group	1	Low project bid price
	2	Construction area restricted
	3	Inconvenient site access
	4	Poor ground conditions
	5	Poor soil quality
	6	Poor terrain conditions
2. Owner group	7	Delayed payment by owner
	8	Delayed decision by owner
	9	Coordination between owner and contractor.
	10	Unreasonable project timeframe
	11	Financial issues related to owner
	12	Project delayed by owner
	13	Delayed approval of materials
	14	Not well-defined scope of work
	15	Delayed land expropriation by owner
	16	Change order from owner during construction

2. Owner group	17	Late issue of approval documents by owner.
	18	Unclear assignment of responsibility near province boundaries
3. Contractor group	19	Difficulties in financing project by contractor
	20	Poor communication between contractor and other parties
	21	Conflict between contractor and other parties
	22	Poor resource management
	23	Necessity to re-do work due to contractor failings
	24	Ineffective planning management by contractor
	25	Insufficiently skilled technical staff
	26	Insufficient equipment and vehicles for the work
	27	Poor quality control
	28	Improper construction method
	29	Contractor cash flow
4. Consultant group	30	Consultant too lenient
	31	Poor coordination between the consultant and contractor(s)
	32	Delay in implementing inspection by consultant
	33	Poorly qualified inspector
	34	Insufficient inspectors
5. Design group	35	Delayed design work
	36	Mistakes in design
	37	Inappropriate design
6. Laborers group	38	Low labor productivity
	39	Insufficiently skilled equipment operator
	40	Insufficient laborers
	41	Personal conflict between laborers and management team
	42	Personal conflict among laborers
7. Materials and equipment group	43	Lack of equipment efficiency
	44	Shortage of equipment
	45	Changes in material types and specifications during construction
	46	Shortage in materials
8. External group	47	Political situation
	48	Exchange rate fluctuation under contract
	49	Change in loans policy by bank
	50	Weather conditions
	51	Monopoly market
	52	Oil price increase
	53	Public events

3.2.2 Data Analysis

1) Ranking of Delay Causes

The suggested delay causes were ranked by severity index. The following formula was used to rank them on the basis of impact level as identified by the participants:

$$\text{Severity index (\%)} = \sum a(n/N)*100/5 \qquad (1)$$

where a = severity level, which ranges from 0 for no influence up to 5 for very high, n = frequency of response and N = total number of responses.

Accordingly, if all participants respond that a particular cause has no influence, then that cause gains a severity index of 0, meaning that it is not relevant to project delays and ranks last. Conversely, if all respond that it has a very high influence, then the severity index is 100, meaning that this cause is very highly relevant and is the first in rank. Table 3.2 shows the possible ranges for the severity index and the corresponding impact level.

Table 3.2 Severity Index and Corresponding Impact Level

Severity index (%)	Impact level
0	No influence
0-20	Very low
20-40	Low
40-60	Moderate
60-80	High
80-100	Very high

The severity index for each cause was calculated according to Eq. (1) from the individual contractors', owners' and consultants' responses as well as from the combined responses.

A group index was calculated by using the average of the severity indexes of the causes in each group such that

$$\text{Group severity index (\%)} = \sum_{i=1}^{n} X_i / n \qquad (2)$$

where X_i = severity index of cause i in the group and n = number of causes in the group.

2) Rank Correlation

The Spearman rank correlation was used to measure the correspondence between pairs of rankings in the sample observations, thereby comparing how well the contractors, owners and consultants agree on the causes of delay. A perfect positive correlation (r_s = +1) indicates that the object is ranked identically in the compared samples, whereas a perfect negative correlation (r_s = -1) indicates that the rankings have an exactly inverse relationship. This means that sample correlations close to unity in magnitude imply a good correlation, whereas values near 0 indicate low or no correlation. The Spearman rank correlation formula is as follows:

$$r_s = 1 - \left[6 * \sum d^2 / (n^3 - n) \right] \qquad (3)$$

where r_s = Spearman rank correlation coefficient between two parties, d = difference between ranks assigned to variables for each cause and n = number of pairs of rankings.

3.3 Results and discussions

3.3.1 Respondent Personal Information

The questionnaire was sent to a total of 50 contractors, 40 owners and 30 consultants. A total of 35 contractors (70.0%), 31 owners (77.5%) and 24 consultants (80.0%) completed the questionnaire as shown in Table 3.3 All of the respondents were engineers. Among them, 30 had between 5 and 10 years of experience, 18 had 10 to 15 years of experience and 42 had over 15 years of experience. The average was approximately 16 years' experience.

Table 3.3 List of Responses (percent)

Respondents	Questionnaire distributed	Responses returned	Percentage of responses
Contractors	50	35	70.0%
Owners	40	31	77.5%
Consultants	30	24	80.0%
Total	120	90	75.0%

3.3.2 Ranking of Delay Causes by Group

1) Project Group

Six delay causes are listed in this group. Table 3.4 shows the severity index and ranking of each one from the viewpoint of contractors, owners and consultants, as well as the combined viewpoint (the combination of contractor, owner and consultant views). It is clear that the most severe cause of delays from the combined viewpoint is "Low project bid price". However, the rankings from the individual viewpoints are quite different.

The results also show that the difference between the most and least severe causes in this group is 37.22%.

Table 3.4 Ranking of Delay Causes in Project Group

Cause	Combined' view		Contractors' view		Owners' view		Consultants' view	
	Severity index (%)	Rank	Severity index (%)	Rank	Severity index (%)	Rank	Severity index (%)	Rank
Low project bid price	60.00	1	76.57	1	39.35	5	62.50	1
Poor soil quality	46.89	2	43.43	6	47.10	1	51.67	2
Poor terrain conditions	46.22	3	48.00	4	45.81	2	44.17	3
Poor ground conditions	45.11	4	47.43	5	45.81	2	40.83	4
Inconvenient site access	43.78	5	50.86	2	40.65	4	37.50	6
Construction area restricted	42.67	6	49.14	3	38.71	6	38.33	5

2) Owner Group

This group includes twelve causes. Table 3.5 presents the rankings from each viewpoint, showing that the most severe cause from all viewpoints is “Delayed payment by owner”.

The most severe causes in the rankings by contractors, owners, consultants and the combined view are quite similar, with 1 to 3 in the rankings being “Delayed payment by owner”, “Financial issues related to owner” and “Delayed decision by owner”, respectively, except in the case of owners and consultants.

The results also indicate that the most severe causes in this group are quite distinct. In the combined view, for example, there is a wide span of severity ranging from 38.00% to 81.56%, a difference of 43.56%. That is, the causes range from low to very high severity and the difference in its severity index.

Table 3.5 Ranking of Delay Causes in Owner Group

Cause	Combined’ view		Contractors’ view		Owners’ view		Consultants’ view	
	Severity index (%)	Rank	Severity index (%)	Rank	Severity index (%)	Rank	Severity index (%)	Rank
Delayed payment by owner	81.56	1	91.43	1	73.55	1	77.50	1
Financial issues related to owner	75.11	2	85.71	2	68.39	2	68.33	2
Delayed decision by owner	57.33	3	71.43	3	48.39	4	48.33	4
Change order from owner during construction	51.33	4	57.71	8	45.81	5	49.17	3
Coordination between owner and contractor.	49.78	5	60.00	6	43.87	6	42.50	8
Late issue of approval documents by owner.	49.56	6	61.14	5	40.65	8	44.17	6
Unreasonable project timeframe	49.33	7	50.86	10	52.26	3	43.33	7
Not well-defined scope of work	48.00	8	58.86	7	41.94	7	40.00	11
Delayed land expropriation by owner	47.11	9	53.14	9	40.65	8	46.67	5
Delayed approval of materials	46.89	10	63.43	4	37.42	10	35.00	12
Project delayed by owner	41.33	11	48.00	11	32.90	11	42.50	8
Unclear assignment of responsibility near province boundaries	38.00	12	44.57	12	28.39	12	40.83	10

3) Contractors Group

There are eleven causes in the contractors group. Table 3.6 shows that the cause with the highest severity from the combined, contractors', owners' and consultants' views is "Contractor cash flow". The top and second ranked causes from all viewpoints are quite similar. In the combined view, the range of severity for all causes is narrow, ranging from 46.22% to 84.22%, meaning that the effect on delays is moderate to very high.

Table 3.6 Ranking of Delay Causes in Contractor Group

Cause	Combined' view		Contractors' view		Owners' view		Consultants' view	
	Severity index (%)	Rank	Severity index (%)	Rank	Severity index (%)	Rank	Severity index (%)	Rank
Contractor cash flow	84.22	1	88.00	1	78.71	1	85.83	1
Difficulties in financing project by contractor	77.11	2	82.29	2	75.48	2	71.67	3
Insufficient equipment and vehicles for the work	70.89	3	77.71	3	61.29	3	73.33	2
Poor quality control	63.11	4	71.43	4	54.19	6	62.50	5
Insufficiently skilled technical staff	59.78	5	61.14	5	57.42	4	60.83	6
Ineffective planning management by contractor	57.33	6	52.00	7	57.42	4	65.00	4
Improper construction method	56.00	7	58.29	6	49.68	8	60.83	6
Poor communication between contractor and other parties	52.00	8	49.71	9	52.90	7	54.17	8
Necessity to re-do work due to contractor failings	49.78	9	50.29	8	46.45	10	53.33	9
Poor resource management	46.44	10	49.71	10	41.94	11	47.50	11
Conflict between contractor and other parties	46.22	11	42.86	11	47.74	9	49.17	10

4) Consultant Group

Table 3.7 shows the severity index and ranking of each cause under the consultants group. five causes are identified under this group.

Table 3.7 shows the results that the most severe cause from the combined view, owners' view and consultants' view is "Insufficient inspectors". It is clear from the results that the severity index ranking from the combined view has a narrow span, with severity indexes ranging from 41.33% to 52.00%. That is, all causes in this group have a moderate effect on road construction project delays.

Table 3.7 Ranking of Delay Causes in Consultant Group

Cause	Combined' view		Contractors' view		Owners' view		Consultants' view	
	Severity index (%)	Rank	Severity index (%)	Rank	Severity index (%)	Rank	Severity index (%)	Rank
Insufficient inspectors	52.00	1	68.00	2	43.23	1	40.00	1
Delay in implementing inspection by consultant	50.44	2	70.86	1	39.35	4	35.00	3
Poor coordination between the consultant and contractor(s)	47.78	3	61.71	4	40.65	2	36.67	2
Poorly qualified inspector	47.78	3	65.71	3	38.71	5	33.33	4
Consultant too lenient	41.33	5	52.00	5	40.65	2	26.67	5

5) Design Group

Table 3.8 shows the severity index and ranking of each cause in the design group. The most severe of the three causes in this group is "Delayed design work" for all viewpoints. The rankings from the contractors', owners', consultants' and combined views are all similar. The span of severity values in the combined view is quite narrow, ranging from 44.22% to 48.22%. That is, all causes in this group have a moderate effect on road construction project delays.

Table 3.8 Ranking of Delay Causes in Design Group

Cause	Combined' view		Contractors' view		Owners' view		Consultants' view	
	Severity index (%)	Rank	Severity index (%)	Rank	Severity index (%)	Rank	Severity index (%)	Rank
Delayed design work	48.22	1	46.29	1	47.74	1	51.67	1
Mistakes in design	46.22	2	44.57	2	45.16	2	50.00	2
Inappropriate design	44.22	3	44.57	3	44.52	3	43.33	3

6) Laborers Group

Table 3.9 shows the severity index and ranking of each cause in the laborers group. Five causes are identified in this group. All viewpoints except owners find that "Insufficient laborers" is the most severed delay cause; this ranks second for owners.

All of the rankings in Table 3.7 are quite similar. The severity index from the combined

view ranges from 39.78% to 63.33%, meaning that these delay causes have an impact ranging from low to high.

Table 3.9 Ranking of Delay Causes in Laborers Group

Cause	Combined' view		Contractors' view		Owners' view		Consultants' view	
	Severity index (%)	Rank	Severity index (%)	Rank	Severity index (%)	Rank	Severity index (%)	Rank
Insufficient laborers	63.33	1	68.57	1	50.97	2	71.67	1
Insufficiently skilled equipment operator	61.33	2	68.57	2	52.90	1	61.67	2
Low labor productivity	58.22	3	68.00	3	50.97	2	53.33	3
Personal conflict between laborers and management team	43.11	4	44.00	4	41.94	4	43.33	4
Personal conflict among laborers	39.78	5	40.00	5	36.77	5	43.33	4

7) Materials and Equipment Group

The material and equipment group comprises four delay causes. Table 3.10 shows that the most severe cause in the combined view is "Lack of equipment efficiency". The rankings from the contractors', owners' and combined views are quite similar, while consultants rank "Lack of equipment efficiency" third. However, first, second and third most severe causes are all grouped together.

The range of severity index values from the combined view is narrow, with values from 55.11% to 65.33%. That is, their impact on project delays ranges from moderate to high.

Table 3.10 Ranking of Delay Causes in Materials and equipment Group

Cause	Combined' view		Contractors' view		Owners' view		Consultants' view	
	Severity index (%)	Rank	Severity index (%)	Rank	Severity index (%)	Rank	Severity index (%)	Rank
Lack of equipment efficiency	65.33	1	74.86	2	56.77	1	62.50	3
Shortage of equipment	65.11	2	75.43	1	52.26	2	66.67	1
Shortage in materials	58.22	3	61.71	3	48.39	3	65.83	2
Changes in material types and specifications during construction	55.11	4	61.14	4	44.52	4	60.00	4

8) External Group

Seven delay causes are listed in the external group. Table 3.11 shows that the most severe cause from all viewpoints is “Oil price increase”. There is no significant difference in the ranking of causes among the viewpoints. There is a wide span of severity index in the combined ranking, ranging from 30.00% to 64.67%. This indicates that these delay causes have an impact ranging from low to high.

Table 3.11 Ranking of Delay Causes in External Group

Cause	Combined’ view		Contractors’view		Owners’ view		Consultants’view	
	Severity index (%)	Rank	Severity index (%)	Rank	Severity index (%)	Rank	Severity index (%)	Rank
Oil price increase	64.67	1	80.00	3	55.48	1	54.17	1
Change in loans policy by bank	64.22	2	80.57	1	55.48	1	51.67	2
Exchange rate fluctuation under contract	58.44	3	80.57	1	44.52	4	44.17	3
Monopoly market	53.33	4	78.29	4	37.42	6	37.50	5
Weather conditions	46.22	5	48.57	5	45.16	3	44.17	3
Public events	42.22	6	45.14	6	42.58	5	37.50	5
Political situation	30.00	7	40.57	7	22.58	7	24.17	7

3.3.3 Overall Ranking of Delay Causes

The severity index and ranking of all investigated 53 causes of delay in road construction projects from the four viewpoints are listed in Table 3.12.

There are two causes with a severity index above 80% in the combined viewpoint: “Contractor cash flow” and “Delayed payment by owner”. There are also three causes with a severity index above 70%: “Difficulties in financing project by contractor”, “Financial issues related to owner” and “Insufficient equipment and vehicles for the work”. A discussion on these top five delay causes from combined viewpoint can be made as follows.

- **Contractor cash flow**

The issue of contractor cash flow is found to be the top cause of delays in road construction projects in Laos. Many contracting companies in Laos are not only involved in road construction projects, so they have many other activities going on and may have taken on more contracted projects than cash flow can support. As a result, many contractors have put revolving money into other projects. Further, this problem commonly results from the second-ranked cause of delays according to the combined viewpoint: "Delayed payment by owner". Payments may be overdue for a particular project or, in some cases, payments from previously completed projects for the same owner are delayed [43]. These are important causes of “Contractor cash flow”.

- **Delayed payment by owner**

"Delayed payment by owner" is the second-ranked cause of project delays. It has a number of causes, including: project cost exceeds original estimate; payments are staged and payment approval is slow; lack of clear payment guidelines; and increased project cost because of loan interest. Especially, disaster-recovery projects often cost more than the initial estimate.

Late payment appears to be a critical cause of delays in other countries, such as the West Bank in Palestine [1] (rank 4), Saudi Arabia [44],[45] (rank 2 in both studies), Kuwait [46] (rank 2), Malaysia [47] (rank 4), Ghana [3] (rank 1), and Nigeria [48] (rank 2).

- **Difficulties in financing project by contractor**

Many contractors have difficulties in financing projects in Laos. This has some connection with the second-ranked cause of delays: "Delayed payment by owner". Also, contractors may be taking on business projects beyond their capability to invest because of insufficient financial resources; they may have poor cash flow management; and most road construction projects in Laos require the contractor to cover the investment required until the project is accepted by the owner (generally the Laos government), after which payment is made according to the contract. The owner usually pays in stages for 3 to 7 years after completion depending on the size of the project and annual budget plan.

- **Financial issues related to owner**

There are a number of factors relating to the financial status of the owner that can cause problems, such as: approvals of additional projects not included in the original annual master plan; the project has a much higher value than originally estimated; and payment approvals from owner delayed, so interest accrues on project cost. Also, in many cases of disaster-recovery projects, the quantity of work turns out to be higher than originally estimated.

- **Insufficient equipment and vehicles for the work**

Many road construction projects in Laos have to be carried out using less equipment and vehicles than initially specified in the contract. Further, the quality of equipment and/or vehicles is sometimes inadequate. The causes of this issue may be the insufficient examination of the contract documents. It is not unknown for a contractor to have another ongoing project at the same time and to move some equipment and/or vehicles to that project.

Only three causes have a severity index of less than 40% in the combined viewpoint, meaning that they have a low impact level: “Personal conflicts among laborers”; “Unclear assignment of responsibility near province boundaries”; and “Political situation”.

Table 3.12 Overall Ranking of Delay Causes

Cause	Combined view		Contractors' view		Owners' view		Consultants' view	
	Severity index (%)	Rank	Severity index (%)	Rank	Severity index (%)	Rank	Severity index (%)	Rank
Contractor cash flow	84.22	1	88.00	2	78.71	1	85.83	1
Delayed payment by owner	81.56	2	91.43	1	73.55	3	77.50	2
Difficulties in financing project by contractor	77.11	3	82.29	4	75.48	2	71.67	4
Financial issues related to owner	75.11	4	85.71	3	68.39	4	68.33	6
Insufficient equipment and vehicles for the work	70.89	5	77.71	9	61.29	5	73.33	3
Lack of equipment efficiency	65.33	6	74.86	12	56.77	8	62.50	10
Shortage of equipment	65.11	7	75.43	11	52.26	14	66.67	7
Oil price increase	64.67	8	80.00	7	55.48	9	54.17	17
Change in loans policy by bank	64.22	9	80.57	5	55.48	9	51.67	21
Insufficient laborers	63.33	10	68.57	16	50.97	16	71.67	4
Poor quality control	63.11	11	71.43	13	54.19	11	62.50	10
Insufficiently skilled equipment operator	61.33	12	68.57	16	52.90	12	61.67	13
Low project bid price	60.00	13	76.57	10	39.35	44	62.50	10
Insufficiently skilled technical staff	59.78	14	61.14	24	57.42	6	60.83	14
Exchange rate fluctuation under contract	58.44	15	80.57	5	44.52	30	44.17	30
Low labor productivity	58.22	16	68.00	18	50.97	16	53.33	19
Shortage in materials	58.22	16	61.71	22	48.39	19	65.83	8
Delayed decision by owner	57.33	18	71.43	13	48.39	19	48.33	27
Ineffective planning management by contractor	57.33	18	52.00	32	57.42	6	65.00	9
Improper construction method	56.00	20	58.29	29	49.68	18	60.83	14
Changes in material types and specifications during construction	55.11	21	61.14	24	44.52	30	60.00	16
Monopoly market	53.33	22	78.29	8	37.42	48	37.50	45
Insufficient inspectors	52.00	23	68.00	18	43.23	34	40.00	42
Poor communication between contractor and other parties	52.00	23	49.71	37	52.90	12	54.17	17
Change order from owner during construction	51.33	25	57.71	30	45.81	25	49.17	25
Delay in implementing inspection by consultant	50.44	26	70.86	15	39.35	44	35.00	49

Coordination between owner and contractor.	49.78	27	60.00	27	43.87	33	42.50	38
Necessity to re-do work due to contractor failings	49.78	27	50.29	36	46.45	24	53.33	19
Late issue of approval documents by owner.	49.56	29	61.14	24	40.65	39	44.17	30
Unreasonable project timeframe	49.33	30	50.86	34	52.26	14	43.33	34
Delayed design work	48.22	31	46.29	44	47.74	21	51.67	21
Not well-defined scope of work	48.00	32	58.86	28	41.94	36	40.00	42
Poorly qualified inspector	47.78	33	65.71	20	38.71	46	33.33	51
Poor coordination between the consultant and contractor(s)	47.78	33	61.71	22	40.65	39	36.67	48
Delayed land expropriation by owner	47.11	35	53.14	31	40.65	39	46.67	29
Delayed approval of materials	46.89	36	63.43	21	37.42	48	35.00	49
Poor soil quality	46.89	36	43.43	50	47.10	23	51.67	21
Poor resource management	46.44	38	49.71	37	41.94	36	47.50	28
Weather conditions	46.22	39	48.57	40	45.16	28	44.17	30
Mistakes in design	46.22	39	44.57	46	45.16	28	50.00	24
Conflict between contractor and other parties	46.22	39	42.86	51	47.74	21	49.17	25
Poor terrain conditions	46.22	39	48.00	41	45.81	25	44.17	30
Poor ground conditions	45.11	43	47.43	43	45.81	25	40.83	40
Inappropriate design	44.22	44	44.57	46	44.52	30	43.33	34
Inconvenient site access	43.78	45	50.86	34	40.65	39	37.50	45
Personal conflict between laborers and management team	43.11	46	44.00	49	41.94	36	43.33	34
Construction area restricted	42.67	47	49.14	39	38.71	46	38.33	44
Public events	42.22	48	45.14	45	42.58	35	37.50	45
Consultant too lenient	41.33	49	52.00	32	40.65	39	26.67	52
Project delayed by owner	41.33	49	48.00	41	32.90	51	42.50	38
Personal conflict among laborers	39.78	51	40.00	53	36.77	50	43.33	34
Unclear assignment of responsibility near province boundaries	38.00	52	44.57	46	28.39	52	40.83	40
Political situation	30.00	53	40.57	52	22.58	53	24.17	53

3.3.4 Top Five Causes of Delay from each viewpoint

The top five delay causes from each viewpoint are picked up from Table 3.12 and listed in Table 3.13 - 3.15 with their related groups. They are similar, and three causes, “Delayed payment by owner”, “Contractor cash flow” and “Difficulties in financing project by contractor”, are included in all tables. “Insufficient equipment and vehicles for the work” is included in the tables from owners’ and consultants’ viewpoint, indicating that there is only one cause different between them. It can be said that the recognition of the important

causes of project delay is basically shared among contractors, owners and consultants. However, the level of the severity evaluated by contractors, owners and consultants is different. Severity indexes from the contractors' viewpoint are considerably higher than from the owners' and consultants' viewpoint. This fact can be also recognized from Table 3.12.

Table 3.13 Top Five Delay Causes and Related Groups from Contractors' Viewpoint

Cause	Related group	Severity index (%)	Rank
Delayed payment by owner	Owner	91.43	1
Contractor cash flow	Contractor	88.00	2
Financial issues related to owner	Owner	85.71	3
Difficulties in financing project by contractor	Contractor	82.29	4
Change in loans policy by bank	External	80.57	5

Table 3.14 Top Five Delay Causes and Related Groups from Owners' Viewpoint

Cause	Related group	Severity index (%)	Rank
Contractor cash flow	Contractor	78.71	1
Difficulties in financing project by contractor	Contractor	75.48	2
Delayed payment by owner	Owner	73.55	3
Financial issues related to owner	Owner	68.39	4
Insufficient equipment and vehicles for the work	Contractor	61.29	5

Table 3.15 Top Five Delay Causes and Related Groups from Consultants' Viewpoint

Cause	Related group	Severity index (%)	Rank
Contractor cash flow	Contractor	85.83	1
Delayed payment by owner	Owner	77.50	2
Insufficient equipment and vehicles for the work	Contractor	73.33	3
Difficulties in financing project by contractor	Contractor	71.67	4
Insufficient laborers	Laborers	71.67	4

3.3.5 Ranking of Groups

For this study, the causes of delay were classified into eight groups as described above. Here, these groups are ranked according to the grouped severity index of their causes as determined by contractors, owners, consultants. The results are presented in Table 3.16.

From the combined viewpoint, the three top groups are: Materials and equipment; Contractor; and Laborers. The range of severity index is narrow, from 46.22% to 60.94%. The top three groups from the contractors' viewpoint are: Materials and equipment;

External; and Consultant. Those from owners' and consultants' viewpoint are the same: Contractor; Materials and equipment; and Laborers. The group with the lowest severity index is the Project group from contractors' viewpoint, and the Consultant group from owners' and consultants' viewpoint. Again, the group ranking from owners' and consultants' viewpoint is quite similar.

Table 3.16 Group Ranking

Group	Combined view		Contractors' view		Owners' view		Consultants' view	
	Severity index (%)	Rank	Severity index (%)	Rank	Severity index (%)	Rank	Severity index (%)	Rank
Materials and equipment	60.94	1	68.29	1	50.48	2	63.75	1
Contractor	60.26	2	62.13	5	56.66	1	60.26	2
Laborers	53.16	3	57.83	6	46.71	3	53.16	3
Owner	52.94	4	62.19	4	46.18	4	48.19	5
External	51.30	5	64.82	2	43.32	6	41.90	7
Consultant	47.87	6	63.66	3	40.52	8	34.33	8
Project	47.44	7	45.06	8	42.90	7	45.83	6
Design	46.22	8	45.14	7	45.81	5	48.33	4

3.3.6 Severity rank correlation

The Spearman rank correlation is used to measure the correspondence between contractors' and owners' responses, contractors' and consultants' responses, and owners' and consultants' responses. Equation (3) is used for this purpose. There is relatively good agreement (positive correlation) between contractors' and owners' rankings of delay causes, with $r_s = +0.474$. There is also good agreement between contractors and consultants, with $r_s = +0.465$. Between owners and consultants, the correlation is $r_s = +0.831$, which is a very good relative agreement between the two parties in the ranking of delay causes. This may be because the consultant is usually the agents acting owners' behalf.

3.4 Recommendations

The following recommendations are made to all parties as ways to reduce and control delays in road construction projects:

The project owner, meaning the Laos government, should pay special attention to the following points:

- Making the required decisions on time so as to improve communications and

coordination with other construction parties (donors, consultants and contractors).

- Making efforts to modify and improve regulations, contracts and laws related to road projects to address the causes of delay shown to have a high severity index.
- Implementing annual programs for continuous training in cooperation with the contractor's union as a way to improve managerial skills, the checking and repair of equipment and vehicles, site engineering ability and labor skills.
- Resolving the problem of delayed payments to ensure that staged payments are made to contractors on time, since late payments affect a contractor's ability to finance the work. The result is time overruns and contracting companies may also use late payments as a reason to bargain with the Laos government (owner) in the case of delay.
- Allowing sufficient time to make adequate preparations for a project. This includes drawing up a planning schedule, particularly for the design phase to avoid the need for changes; detailed and comprehensive investigations of the site and site environment; and fully documenting all information before finally submitting the tender. This will help to avoid and later errors and thereby help avoid or minimize time and/or cost overruns.
- Re-checking the background, capabilities and resources of contracting companies before awarding the contract to the lowest bidder.

Contractors should consider the following:

- Ensuring the availability of sufficient resources in terms of budget, engineers, staff, laborers, equipment, vehicles and others that are necessary before bidding and making efforts to carry out projects at the specified time.
- Improving management of financial resources and cash flow by requesting staged payments.
- Ensuring that sufficiently skilled managers, engineers and staff are involved in the project.
- Providing expert training for laborers in relevant work practices so as to improve skills before beginning work, especially in the case of large projects or high-risk workplaces.
- Taking responsibility for the specified quality, cost and schedule.
- Improving communications and coordination with other construction parties (donors, owners, consultants and others) so as to obtain good results.

Consultants should look to the following:

- Providing all necessary information and documentation for the road construction project to other construction parties and, if possible, preparing sample documents and a recommended timeline for document processing.

- Providing owners and contractors with payment documents in more timely way, because the severity index of "contractor revolving money" and "owner payment is postponing" are the top of causes of delays in road construction projects.

3.5 Conclusion

In this study, the causes of these delays are elucidated through a questionnaire survey, with the severity of each cause obtained from the viewpoints of contractors, owners and consultants. The 53 possible causes of delay included in the questionnaire were obtained through a detailed literature review and in consultation with expert civil engineers in Laos. The identified causes are combined into eight groups: project, owner, contractor, consultant, design, laborers, materials and equipment and external. The questionnaire was completed by 35 contractors, 31 owners and 24 consultants.

The top five causes of delay by severity index in the ranking obtained from the results are the following:

- Contractor cash flow;
- Delayed payment by owner;
- Difficulties in financing project by contractor;
- Financial issues related to owner; and
- Insufficient equipment and vehicles for the work.

The Spearman rank correlation showed that there is relatively good overall agreement between contractors and owners ($r_s = +0.474$), contractors and consultants ($r_s = +0.465$) and especially between owners and consultants ($r_s = +0.831$) as to the severity rank of delay causes.

Further analysis of the data obtained from the questionnaire showed the following:

- There are no causes of delay with a severity index less than 20%;
- Severity indexes from the contractors' viewpoint are considerably higher than from the owners' and consultants' viewpoint. There are no causes with a severity index of less than 40% from the contractors' viewpoint; and
- The group severity index from the combined viewpoint ranges between 46.22% and 60.94%. This indicates that all the identified causes are highly relevant to the problem of delays in road construction projects in Laos.

The results of this study suggest that a necessary future task is to use the severity index of delay causes as a baseline for improving rules, agreements, management, administration and planning. The modified processes should be tested and used, then checked against percentage delays to determine if there has been any improvement. This process should be iterated to make the project implementation process as good as possible.

CHAPTER 4

Comprehensive Assessment of Bridge Management Capability of Governments across Countries Receiving Development Assistance

4.1 Introduction

Lack of adequate, reliable, and comprehensive information on bridge maintenance hinders the effective development and implementation of appropriate bridge management systems in most developing countries. Therefore, the purpose of this study is an attempt to fill the knowledge gap and provide practical recommendations to improve the current situation, which in this article is written based on data compiled from country reports of developing countries participated in JICA-supported annual bridge maintenance training courses conducted during 2016-2020. In total, 102 participants from 42 countries participated in the training courses, more specifically by the study carried out on the following main activities:

- Compile bridge maintenance issues of all participating developing countries;
- Summarize all identified bridge management issues in main issue areas; and
- Analyze each issue by using transportation asset management (TAM) maturity scale level.

The AASHTO Transportation Asset Management Guide[49] is a strategic and systematic process of operating, maintaining, upgrading, and expanding physical assets effectively throughout their life cycle. The five-level maturity scale, which can be used to understand the position of the agency in a wide range of TAM practices and is used throughout this guide.

Level 1, “Initial” does not have effective support from strategy, processes, or tools. There may be a lack of motivation to improve, and the mandated data are collected but not used for internal management or for communication with stakeholders. Level 2, “Awakening” is the recognition of a need and basic data collection. However, there is often a reliance on the heroic effort of individuals. Further, basic data collection and processing exist. In addition, data collection beyond mandatory items is used to answer narrowly defined management questions and issues. Level 3, “Structured” refers to shared understanding, motivation, and coordination. It involves development of processes and tools. Data are processed into performance measures for upward communication, and the objectives are communicated downward. However, there is minimal compatibility or communication of performance between organizational units or disciplines. Level 4, “Proficient” refers to the expectations and accountability drawn from asset management strategy, processes, and tools. A common general understanding of asset performance exists at all levels, both horizontally and vertically. Further, performance information is used to regulate ongoing activities, particularly resource allocation and cost control. Finally, Level 5, “Best Practice” refers to asset management strategies, processes, and tools that are routinely evaluated and improved. Asset management information technology is used to design newer, more efficient tools and processes on a regular basis.

Communication to information, decision-making quality, and continuous improvement exists at all levels of the organization. (AASHTO, 2013) [49].

4.2 Research Methodology

4.2.1 Source of Countries Reports

Country reports were prepared by participants from developing countries who participated in a one-month training program from February to March as shown in Table 4.1 on bridge maintenance during 2016-2020, as shown in the table, 102 government officials from the relevant authorities of 42 developing countries completed this training program, and country reports were one of the key outputs of the program that participants from each participating country were required to prepare and submit.

Table 4.1 Course period and participants of JICA Bridge Maintenance Training (2016-2020)

Course year and period	Participating countries
2016 March 6 - April 2	Bhutan, Cambodia(2), Democratic Republic of the Congo, Egypt, Mozambique, Myanmar, Palau, Papua New Guinea, Solomon Islands, South Sudan, Sri Lanka(4), Togo, Tunisia, Vietnam, Zambia, Zimbabwe
2017 February 27 - March 24	Bangladesh(2), Cambodia, Democratic Republic of the Congo, Egypt(2), El Salvador(2), Ethiopia, Liberia, Malawi, Marshall Islands, Myanmar, Palau, Papua New Guinea, Philippines, Sri Lanka(2), Togo, Tunisia, Zambia, Zimbabwe
2018 February 25 - March 24	Afghanistan, Bangladesh, Brazil, Egypt, Guinea, Haiti, Liberia, Malawi, Marshall Islands, Mozambique, Nepal, Palau, Philippines, Sri Lanka, South Sudan, Samoa, Sudan, Tanzania, East Timor, Togo, Uganda, Vietnam
2019 February 17 - March 21	Bhutan, Bangladesh, Democratic Republic of the Congo, Egypt, El Salvador, Ethiopia, Cuba, Iraq, Saint Lucia, Mozambique, Nepal, Honduras, Philippines, Sri Lanka, Zambia, Samoa, Sudan, Tanzania, Tunisia, Togo, Uganda
2020 February 16 - March 8	Bhutan, Democratic Republic of the Congo(2), Egypt, Guinea(2), Ghana, Indonesia, Laos, Myanmar, Nicaragua, Ukraine, Philippines, Sri Lanka, Zambia, Sudan, Tanzania, Uganda

The number in parentheses following each country name is the number of multiple participants.

Source: JICA Bridge Maintenance Training Course Country Report year 2016 - 2020

In this study, the authors referred to Saviotti's (2014) study which reviewed early studies and explored the achievements of existing bridges by using bridge assessment, management, and life-cycle analysis. Saviotti's methodology is based on evidence of current bridge condition and scientific and technical procedures rather than sophisticated engineering analysis.

In its analysis, the authors used country reports submitted to the JICA-supported capacity-building program for all 42 participating developing countries. All country reports were prepared in advance before the start of the training course based on a standard template, which consisted of key elements of bridge management, including the following:

- Information on concerned public authority;

- Infrastructure, budget, and expenditure;
- Inspection and evaluation;
- Implementation of bridge maintenance and management;
- Bridge maintenance and management plan;
- Bridge management system; and
- Human resource.

Country reports were prepared with the primary purpose of enhancing the technical capacity of the participants of 42 selected developing countries, who participated in a practical training program implemented by Nagasaki University in Japan with the specific objective of improving understanding of bridge maintenance systems in Japan. It focused on enhancing participants' skills in bridge maintenance and management plans, key principles of inspection and evaluation, and developing action plans to strengthen bridge management systems in home countries.

All participants were required to prepare country reports based on a standard template, which consisted of a set of standard questionnaires as follows:

1. General information on the organization such as, organization's name, number of offices, role of organization and department, number of staff, budgeting process, characteristics of organization, and organizational chart.
2. Infrastructure budget and expenditure including road infrastructure information, revenue (local and donor funding), infrastructure expenditure, special purpose budgets such as road maintenance funds, and issues to ensure bridge maintenance and management.
3. Various inspections and evaluations, such as, of types of existing bridge inventory, standards and guidelines of bridge inspection, the technical level of standards and guidelines, utilization of standards and guidelines, daily inspection (implementation body, method of implementation, budget frequency, data accumulation, equipment), routine inspection (implementation body, method of implementation, budget frequency, data accumulation, equipment), issues of technical level of bridge inspection, implementation body of evaluation of bridge inspection, methodology of evaluation of bridge inspection, methodology of evaluation and outputs of evaluation, overall issues related to bridge inspection, and evaluation of inspection.
4. Implementation of bridge maintenance and management consisting of maintenance and rehabilitation (implementation body, procurement, budget, technical level, equipment, standard, manuals), repair and improvement (implementation body, procurement, budget, technical level, equipment, standard, manuals), issues of maintenance and management (organization, budget, institution), and issues of maintenance and management (technical matters).

5. A bridge maintenance and management plan including bridge maintenance and management plan contents, responsible organization, issues in preparation, and implementation of bridge maintenance and management plans.
6. A bridge management system consisting of objectives and background of BMS, outline of BMS (developer, timing of introduction, cost, user, method of data collection, method of input data, etc.), major functions and items of input data, effects of BMS introduction (work efficiency, relation to PDCA cycle, etc.), issues of introduction BMS (work efficiency, data availability, relation to PDCA cycle, etc.), sustainability, and overall issues of BMS.
7. Human resources involved, such as, human resources at the planning level, inspection and repair work, and human resources of the private sector.

As all the reports were written by individual participants representing the participating countries in the training program, there are certain obvious limitations in understanding the current state of bridge maintenance and management in all participating countries. First, the inconsistency of information in the reports, particularly areas related to situation assessment caused by diverse backgrounds and experiences of the authors; second, the ability to access relevant information in the countries could vary significantly from country to country; therefore, analysis of the information from the country reports should be treated with certain limitations.

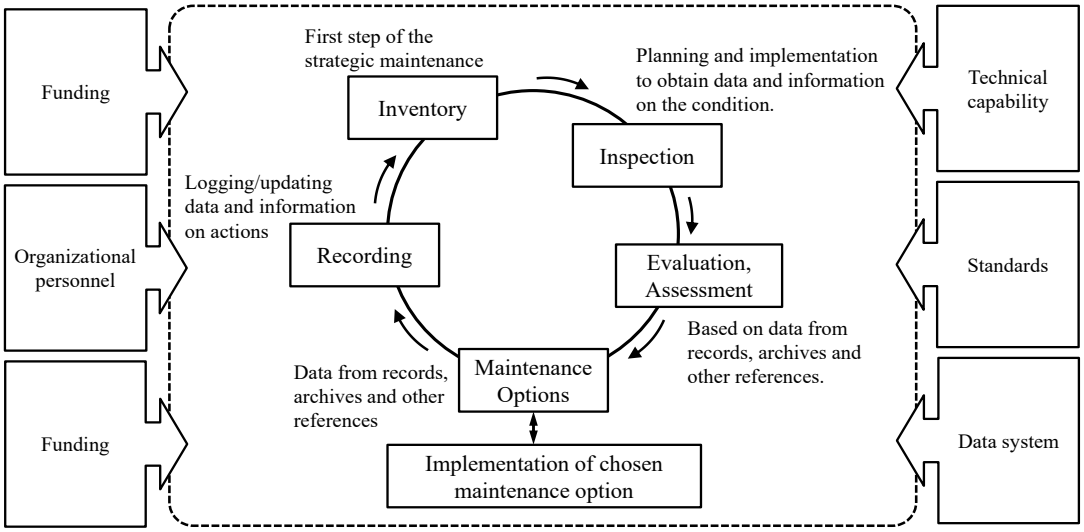

Fig. 4.1 Well-Practiced Cycle of Bridge Maintenance and Management

4.2.2 Methodology to Analyze Classification Level

In this research, the TAM maturity model was used to specify the relative position of the agency for each TAM process. In each TAM maturity scale level of generalized description are shown in Table 4.2.

Table 4.2 Transportation Asset Management Maturity Scale

TAM Maturity Scale Level	Generalized Description
Level 1 Initial	No effective support from strategy, processes, or tools. There may be lack of motivation to improve (Mandated data are collected but not used for internal management or for communication with stakeholders).
Level 2 Awakening	Recognition of a need and basic data collection. However, frequent reliance on heroic effort of individuals (Basic data collection and processing exist. Data collection beyond mandatory items is used to answer narrowly defined management questions and issues).
Level 3 Structured	Shared understanding, motivation, and coordination. Involves development of processes and tools (Data are processed into performance measures for upward communication while objectives are communicated downward. There is a little compatibility or communication of performance horizontally between organizational units or disciplines).
Level 4 Proficient	Expectations and accountability drawn from asset management strategy, processes, and tools (A common general understanding of asset performance exists at all levels horizontally and vertically. Performance information is used to regulate ongoing activities, particularly for resource allocation and cost control).
Level 5 Best Practice	Asset management strategies, processes, and tools are routinely evaluated and improved (Asset management information technology is used to design newer, more efficient tools and processes on a regular basis. A communication to information and decision-making quality and continuous improvement exists at all levels of the organization).

Source: AASHTO Transportation Asset Management Guide

The final project research report on JICA road-bridge maintenance technical cooperation, a well-practiced cycle of bridge maintenance and management, is shown in Fig. 1. The first step of strategic maintenance is “Inventory.” The second step is planning and implementation to obtain data, and information on the condition is “Inventory Plan.” Third step, which is based on data from records, archives, and other references is “Evaluation Assessment.” The fourth step also collects data from records archives, and other references for the implementation of the chosen maintenance option and is called “Maintenance Options.” In the fifth step, involves logging/updating data and information on actions and is called “Recording.” Subsequently there is a return to the first step. In these steps, there are several other necessary components including funding, organizational personnel, equipment, technical capabilities, standards, data systems, and others.

a) Budget issues

For developing countries, the primary issue is insufficient funds for bridge maintenance activities. Therefore, although a system for the maintenance cycle and basic

technical capabilities exist, as the funds for an operation cannot be secured, the maintenance of the system, maintenance of equipment, and implementation of planned activities, including construction works, cannot be conducted. Thus, proper maintenance was impossible. Table 4.3 shows a generalized description in each maturity scale level 1 to 5 under "Issues to ensure budget for bridge maintenance and management"

Table 4.3 Five-level in issues to ensure budget for bridge maintenance and management

Maturity Scale	Generalized Description
Level 1 Initial	No budget, processes, plans, and human resources; further there is lack of tools for bridge maintenance and management. Consequently, there can be a lack of motivation to improve.
Level 2 Awakening	Insufficient funds, lack of human resources for bridge maintenance and management, Insufficient equipment for inspection, basic data collection, and processing are in place but do not usually update the data. There is a lack of skill to manage, plan, and maintain works. The budget for construction and maintenance is consolidated under a single unit.
Level 3 Structured	There are priorities assigned according to the evaluation of bridge conditions, and the budget is allocated based on the priorities; certain human resources possess skills for managing, planning, maintenance works. Basic data collection and processing are in place, but certain inspection data are not usually updated. Certain technology for evaluating bridge conditions exists.
Level 4 Proficient	Sufficient funds for bridge maintenance and management. Possess technology and priorities are assigned according to the evaluation of bridge conditions. Human resources possess the skill to manage, plan, and undertake maintenance works. The basic data collection and processing are in place, but there is a lack of continuity in human resources, or/and budget, or sharing the know-how.
Level 5 Best Practice	There is a sufficient budget for asset management strategies, processes, and tools that are routinely evaluated and improved. Asset management information technology is used to design newer, more efficient tools and processes regularly. Communication to information and decision-making quality and continuous improvement exists at all levels of the organization. Further, there is continuity in action in all processes and good planning.

b) Technical level issues

Developing countries have several technical problems. In certain countries, bridge maintenance work cannot be performed smoothly because of the lack of equipment for bridge maintenance and engineers experienced in bridge maintenance work. Table 4.4 shows the generalized description in each maturity scale level 1 to 5 under the area " Issues of technical level of bridge inspection "

c) Issue of maintenance and management

Developing countries have various problems in addition to budget and technical levels. Even if the budget and technical level are sufficient, certain countries are unable to conduct bridge maintenance work for security and political reasons. Table 4.5 shows the generalized description in each maturity scale level 1 to 5 under area " Issues of maintenance and management (organization, budget, institutions)" from the country report.

Table 4.4 Five-level in issues of technical level of bridge inspection

Maturity Scale	Generalized Description
Level 1 Initial	There is no guideline (limited guideline for inspection), reference inspection method, or inspection procedure. In addition, there is lack of inspection equipment, any bridge database, and inventory (There is no reliable database). Human resources are insufficient and there is lack of enough bridge inspection experience and know-how in these parts.
Level 2 Awakening	In processes developing standard guidelines for bridge inspection, there are insufficient human resources to undertake inspection, planning for inspection, or/and conduct analysis the inventory of bridge database. Bridge inspection is performed visually (lack of equipment and budget for inspection).
Level 3 Structured	The guidelines were developed for bridge inspection and maintenance (but certain parts need to be updated) Insufficient human resources for inspection and maintenance, and insufficient training to perform bridge inspections. There are tools used to prioritize bridge maintenance; certain equipment and budget are not sufficient to satisfy the demand, and often there is a lack of continuity.
Level 4 Proficient	The guidelines developed for bridge inspection and maintenance are updated, there is sufficient human resources for inspection and maintenance, and sufficient training to conduct bridge inspections. Further, there are tools used to prioritize bridge maintenance; certain equipment and budget are not sufficient to satisfy the demand, and there is a lack of continuity occasionally.
Level 5 Best Practice	The guideline for bridge inspection and maintenance is updated, there is sufficient human resources for inspection and maintenance, and sufficient training to carry out bridge inspections. There are tools used to prioritize bridge maintenance, equipment, and budget to meet demand. Further, there is continuity and sustainability.

Table 4.5 Five-level in issues of maintenance and management (organization, institution)

Maturity Scale	Generalized Description
Level 1 Initial	There are no specific organizations or institutions for bridge maintenance and management. There is a lack of experience of technicians or high-quality machines, and a lack of budget for maintenance and management. There is no reliable database.
Level 2 Awakening	There are no specific organizations or institutions for bridge maintenance and management. However, training to conduct bridge maintenance and management has begun. Insufficient experience of technicians or high-quality machines, insufficient budget for maintenance and management, there is guideline for bridge maintenance and management, insufficient equipment and tools for bridge maintenance and management
Level 3 Structured	There are specific organizations or institutions for bridge maintenance and management, that have started training to conduct bridge maintenance and management. There are curtain experienced technicians or high-quality machines. Further, there are human resources for inspection, planning for inspection, and for analysis of the inventory of bridge database. However, budget is insufficient.
Level 4 Proficient	There are specific organizations or institutions and budget for bridge maintenance and management exists. Training to conduct bridge maintenance and management is undertaken, and there are sufficient experienced technicians, equipment, and tools for management. Human resources for inspection, planning for inspection, and analysis of the inventory of bridge database is available. But there is lack of continuity and sustainability.
Level 5 Best Practice	All asset management information technology is used to design newer, more efficient tools and processes on a regular basis. A communication to information and decision-making quality and continuous improvement exists at all levels of the organization.

d) Issues related to maintenance plans

The preparation of a bridge maintenance plan is also a major issue for developing countries. In certain countries, there are no maintenance plans. Table 4.6 shows a generalized description in each maturity scale level 1 to 5 under area " Issues in preparation and implementation of bridge maintenance and management plan"

Table 4.6 Five-level in issues in preparation and implementation of bridge maintenance plan

Maturity Scale	Generalized Description
Level 1 Initial	There is no preparation and implementation of bridge maintenance plan; insufficient budget and human resources; lack of inventory of bridge database.
Level 2 Awakening	There is no preparation and implementation of bridge maintenance plan, but bridge data is being collated and development of systems or using systems for priority bridge maintenance plan has been undertaken. There is insufficient budget and human resources, and lack of inventory of bridge database.
Level 3 Structured	There are systems for preparation and implementation of bridge maintenance plan (for priority bridge maintenance planning), but certain inventories of bridge database is not updated because of insufficient budget, human resources, and equipment and tools.
Level 4 Proficient	There are systems for preparation and implementation of bridge maintenance plan (for priority bridge maintenance planning); inventory of bridge database is usually updated; sufficient human resources, equipment and tools, but occasional insufficient budget resulting in no continuity and sustainability.
Level 5 Best Practice	There are systems for preparation and implementation of bridge maintenance plan (for priority bridge maintenance planning); inventory of bridge database is usually updated; sufficient human resources, equipment and tools, and budget. Thus, continuity and sustainability is maintained.

e) Issues related to Bridge Management System (BMS)

The development of BMS requires advanced technology and a large amount of funds, thus, it is difficult to successfully introduce BMS in developing countries. Table 4.7 shows a generalized description in each maturity scale level 1 to 5 under area “Issues of introduction of BMS (work load for data input, update of data, technical level, maintenance of BMS, collaboration of daily work, etc.)”.

Table 4.7 Five-level in issues related to Bridge Management System (BMS)

Maturity Scale	Generalized Description
Level 1 Initial	No any plan for developing or using the system (BMS).
Level 2 Awakening	Already developed the system (BMS), but not used. Because of lack of budget, insufficient of human resources, lack of inventory the bridge database.
Level 3 Structured	There is the system (BMS) and guideline. Used for priority bridge maintenance planning, but insufficient experience of technicians. Further, inventory of bridge database not usually updated because of insufficient budget.
Level 4 Proficient	There is the system (BMS) and guideline, which is used for asset performance at all levels horizontally and vertically. Performance information is used to regulate ongoing activities, particularly for resource allocation and cost control. However, occasional insufficient budget results in no continuity and sustainability.
Level 5 Best Practice	There is the system (BMS) and guideline, which is used for asset performance at all levels horizontally and vertically. Performance information is used to regulate ongoing activities, particularly for resource allocation and cost control. Further, there is sufficient budget resulting in continuity and sustainability.

f) Human resources issues

In developing countries, the lack of human resources for bridge maintenance is a major issue. Table 4.8 shows the generalized description in each maturity scale level 1 to 5 under the areas "Human resources at planning level" and "Human resources at inspection and repair work".

Table 4.8 Five-level of human resources at planning, at inspection and at repair works

Maturity Scale	Generalized Description
Level 1 Initial	Lack of human resources at the planning level, at inspection, and at repair works. In addition, a lack of budget, equipment and tools.
Level 2 Awakening	There are certain human resources at the planning level. However, it suffers from insufficient budget, inexperienced inspectors and repair workers, insufficient tools system for planning or/and equipment for inspection and repair works.
Level 3 Structured	There is an organization of human resources and tools system for planning level, and sufficiently experienced inspectors and repair workers. However, there is insufficient equipment for inspection and repair works. Further, owing to the insufficient budget, databases are not usually updated.
Level 4 Proficient	There is an organization of human resources and tools system for planning level, and sufficiently experienced inspectors and repair workers. However, there is insufficient equipment for inspection and repair works. Further, due to insufficient budget, database is not usually updated and occasionally there is lack of continuity and sustainability.
Level 5 Best Practice	Human resources exist at all levels of the organization for asset management strategies, planning, and processes, and tools system are routinely evaluated and improved. Consequently, there is continuity and sustainability.

4.3 Results and discussions

Assessment of the current status of bridge maintenance in developing countries was performed based on budget issues, technical issues, issues of maintenance and management, issues related to bridge maintenance plans, issues related to BMSs, and human resource issues. These are divided into levels, as shown in Table 4.9.

4.3.1 Five-level in issues to ensure budget for bridge maintenance and management

According to the report of the various countries, many countries do not have adequate budget for bridge maintenance. It is difficult to secure a sufficient budget for operations and maintenance; for example, in Egypt, the government must provide funds to priority sectors such as educational institutions and medical institutions.

In Liberia and South Sudan, most required materials and equipment are imported from overseas, thereby adding additional costs to maintenance work. For example, in South Sudan, the unit price of concrete, the main material, is three times higher than the price in Japan.

In certain countries, governments do not understand the concept of bridge maintenance well and refuse to allocate the budget for bridge maintenance. In such countries, the priority is the construction of new bridges rather than spending on the maintenance of bridges. In addition, the concept of bridge maintenance has not been understood by the public, as they fail to mobilize resources from various taxes.

In addition to budget shortages, there are also problems such as the inability to prioritize bridges that require maintenance and the inability to estimate costs.

Table 4.9 Developing countries divided into generalized level RAM maturity scale in each issue

Country	Level in issues to ensure budget	Level in issues of technical level of bridge inspection	Level in issues related to organizatio n, and institution	Level in issues related to bridge maintenanc e plan	Level in issues related to BMS	Level in human resources at planning, inspection, and repair
Afghanistan	2	1	1	-	3	-
Bangladesh	2	1	2	2	3	3
Bhutan	4	2	3	2	2	3
Brazil	3	-	2	1	1	1
Cambodia	3	2	2	2	2	1
Cuba	1	-	-	-	2	-
Democratic Republic of the Congo	1	2	2	2	2	-
East Timor	2	1	1	-	-	1
Egypt	4	2	4	3	3	3
El Salvador	2	1	1	1	1	3
Ethiopia	2	2	2	1	3	2
Ghana	2	1	2	2	2	2
Guinea	1	2	1	2	2	2
Haiti	3	1	1	-	3	3
Honduras	2	2	1	2	2	2
Indonesia	-	2	3	1	2	2
Iraq	4	2	1	1	1	-
Laos	2	2	2	-	2	3
Liberia	3	1	1	-	1	-
Malawi	2	2	2	2	1	3
Marshall Islands	2	2	2	1	2	3
Mozambique	1	2	2	2	2	2
Myanmar	2	2	2	1	2	2
Nepal	2	3	3	3	2	3
Nicaragua	-	2	2	1	2	3
Palau	4	-	-	-	-	-
Papua New Guinea	2	2	1	2	3	3
Philippines	4	2	2	3	3	4
Saint Lucia	4	2	2	1	3	2
Samoa	2	2	1	2	2	2
Solomon	-	-	-	-	-	-
South Sudan	3	2	3	2	3	3
Sri Lanka	2	2	2	2	3	3
Sudan	4	1	2	1	1	-
Tanzania	2	2	2	2	2	2
Togo	3	1	1	1	1	1
Tunisia	1	2	2	1	1	3
Uganda	3	2	2	2	3	2
Ukraine	3	2	2	-	2	2
Vietnam	-	-	-	-	-	-
Zambia	4	2	2	2	3	3
Zimbabwe	2	2	2	-	3	3

However, certain countries such as Samoa have a budget for bridge maintenance, which is included in the annual budgetary and funds can be obtained easily from financial institutions in terms of loans and other financial means.

As per the data recorded from each JICA participating country in bridge maintenance training, we concluded that an insufficient budget was a key issue for implementing BMS. Only a few nations have sufficient and dedicated budgets for BMS.

For a developing nation, budget priority was in the construction of new infrastructure rather than for the maintenance of existing structures. According to the report, most of the nations do not have adequate budget for maintenance or the government failed to allocate a budget for maintenance during the initial budget planning. However, few countries such as Sudan, Egypt, the Philippines, and others have proper allocation of budget for maintenance depending on the requirement to carry out the repair and maintenance work in the next fiscal year according to the condition of the structures.

Certain countries with a sufficient budget for maintenance also have other sources of budget, such as national income, transportation tax, and service tolls on highways, in addition to the yearly planned budget for maintenance. Hence, an insufficient budget is a major issue for the implementation of BMS in developing nations, which requires sustainable budget planning in the future.

According to the indicator level of 1-5 in Table 4.6, the initial level with 1 and best practice level of 5 was categorized for all the issues to compare among the nations indicating the success of BMS. Among the 40 countries participating in the bridge maintenance training from 2016-2020, only eight countries have adequate allocation of budget for maintenance work with level 4, another 8 countries with level 3 signifying moderate allocation of budget, 17 countries with level-2 showing poor and no significant allocation of budget for maintenance, and 9 countries with level 1, which clearly states that there is no budget for maintenance.

4.3.2 Five-level in issues of technical level of bridge inspection

Many countries have stated that there is a shortage of equipment to properly inspect bridges. In certain countries, owing to the lack of inspection equipment, such as inspection vehicles and special cameras, the inspection is conducted visually via human eyes, which lacks accuracy. In the case of Sri Lanka, inspections are carried out using a pole camera for a place not accessible to the inspector. In the case of Tanzania, there are no cranes available to inspect high-raise bridges, which makes the inspection difficult in such situations. In any case, many countries have equipment shortages for maintenance and inspection.

Another reason for poor inspection in developing countries is the inexperienced engineers. In certain cases, engineers lack knowledge of maintenance methods or are unable to determine whether the materials used in the field have the properties specified in the specifications.

Regarding technical issues related to bridge inspection, the problem is either a lack of equipment or a lack of qualified technical personnel in most countries. In addition, the lack of proper guidelines for bridge inspection is also one of the primary reasons for the poor and timely inspection. Further, although there are enough qualified and technical personnel to conduct the inspection work, many nations have no basic equipment to undertake inspection work, which hinders the inspection results. For accessibility and good results of inspection work, equipment such as cranes and other basic testing machines are necessary to identify the critical damages on the bridges. Hence, considering the data for all the countries, the lack of proper inspection is primarily due to a lack of experienced technical personnel or equipment facilities. According to my study, none of the nations scored more than Level 2 in this technical issue category.

Thus, regarding technical level issues, the majority of countries lag behind, with only level 2 being the maximum and the majority having no technical capacity in terms of workforce and equipment to conduct bridge inspection.

4.3.3 Five-level in issues of maintenance and management (organization, institution)

Several countries have cited security issues. In this case, El Salvador has gangs controlling a certain area with the bridge, who do not allow the bridge to be inspected. Overall, many believe that the government does not understand the importance of bridge maintenance, resulting in insufficient funds. In certain countries, the standards for bridge maintenance and management are not standardized nationwide. It is difficult to compare the inspection, evaluation, and judgment results for a comprehensive evaluation. The goal is to increase the government's awareness of the concept of bridge maintenance and to share information with local governments.

It is clear from the score of the level that maintenance and management issues are not going to be solved soon. For a developing nation, the priority is not for maintenance and management but for building new infrastructure due to a lack of budget and many other factors. Although many countries have their own bodies to regulate the function of road services and bridges together, for maintenance, the need to prioritize work is far behind.

In this category, only two countries have a score of level 3, signifying implementation of BMS and a good system of management. The rest of the countries have level 2 and below, which shows very poor management and no proper management organization for the implementation of BMS.

4.3.4 Five-level in issues in preparation and implementation of bridge maintenance plan

Many developing countries carry out maintenance work without an appropriate maintenance plan. This is because the inventory of the bridge is insufficient, and it is not possible to make a maintenance plan. In addition, there are no experienced engineers who can formulate realistic maintenance plans. In many developing countries, bridge maintenance is still in its early stages and thus lack ideas to prepare a good maintenance plan. It would be easier to create a maintenance plan if the bridge database and BMS were enhanced. Currently, building a database of bridges is a top priority in many countries. Moreover, in many countries, human resources are not involved in maintenance plans. In most countries, the planning phase is difficult because of the shift of staff generations.

The success of a BMS also depends on a good maintenance plan. Many factors affect the proper planning and implementation of maintenance plans. As stated by certain countries, the lack of proper functioning of BMS affects the proper execution of maintenance planning. Moreover, due to differences in the implementation and managerial bodies, adopting such planning affects the development of an effective maintenance plan. In fact, BMS issues are linked to one another, which affects the entire system if one issue is not solved. Therefore, it is important to follow the sequence to develop a practical and effective BMS from the budget for proper planning.

In this category of maintenance plan, only 3 countries among the 40 participants had level 3, which signifies crossroads between good and bad. The rest of the countries have level 2 and below, showing no maintenance plan either due to lack of funds or several other factors.

4.3.5 Five-level in issues related to Bridge Management System (BMS)

Many countries currently do not have a proper BMS. Although certain countries have BMS, the available data are not comprehensive and accurate. Afghanistan has BMS, but it is rarely used because of the inconsistency of data in the BMS. In Tanzania, they reported that data input in the BMS was difficult because several bridges were designed overseas.

The creation of an appropriate BMS requires experienced technicians and a budget. Therefore, the establishment of BMS is very low in developing countries for not being able to satisfy the budget and technical personnel. The success of BMS depends on good planning with resources and experienced human resources.

It should be noted that many of the participating countries do not have proper BMS, which results in bigger issues to resolve other related issues in this category. Among the 40 participating countries, only 10 have BMS with level 3, which indicates that the

function of BMS is still immature and is in its early stages of function. None of the countries have fully functional BMS at levels 4 and 5. The remaining 30 countries have BMS level 2 and below, which implies there is no BMS or its initial phase.

4.3.6 Five-level human resources at planning level and human resources at inspection and at repair works

Regarding human resources in the bridge maintenance plan, certain countries did not implement the maintenance plan because they had inadequate human resources for planning or only a few people were assigned to this task.

Regarding the human resources for inspection and repair work, relatively large numbers of human resources are allocated compared to the human resources in the plan, still in certain countries, human resources is still insufficient, thus is can be concluded that human resources is generally insufficient.

The human resources issue and proper maintenance planning have failed to implement a good BMS in the country. Similar to all the issues in the above category, there are no better changes in this category. It was stated in the report that many of the human resources issue are due to improper planning and placement of wrong people in the wrong place. However, many of them have stated the lack of experience in conducting bridge inspection works and knowledge of know-how in bridge maintenance works. Considering the report and from a general perspective, bridge work is a skill-specific job that requires extensive training and judgment to conduct effective maintenance work.

In this category, only the Philippines scored level 4, which indicates that human resources and workforce are not an issue for the country. Fifteen other countries scored level 3, which shows that they have barely sufficient manpower to check the general work of bridges, and the rest of the countries had a score of 2, which signifies that there exist major issues in human resources to carry out the conduct of BMS in the country.

4.4 Recommendation and Conclusion

BMS issues are linked to one another. To implement BMS, we need to carefully plan the sequence of methods to adopt them realistically. The issues and nature of the problem for developing countries are similar, and are mostly governed by a lack of budget and qualified technical personnel to execute in the field. Therefore, the following are certain recommendations from this report to achieve higher score levels in each category of issues in all developing countries.

[1] Although budget issues may appear to be one of the core problems for developing nations, considering the structures' long-term benefits and safety, there will be greater benefit in allocating budget initially. It is important to at least allocate the basic

maintenance budget at the initial stage to carry out minor repair works that will safeguard millions in the future. Therefore, management along with the technical team should propose a budget for the government to resolve the issue at the earliest and achieve level 4 and above in this category.

[2] The quality of bridge inspection primarily depends on the qualified technical personnel and the availability of equipment to aid the inspection process. It is recommended that specialized bridge inspectors should be trained regularly and deputed in bridge work to gain more experience. We have found out that in many countries, engineers have to take responsibility for all kinds of work and lose focus on a particular job. Moreover, the frequent change in technical personnel in the organization affects the efficiency of the inspector. Hence, it is suggested that the technical personnel should be placed in the right work to avoid job mismatch. Regarding equipment, budget constraints may be the common reason for all countries. However, basic equipment such as safety gears for inspectors, hammer, and crane should be necessary to identify and inspect damages on bridges to score level 4 and above.

[3] For all developing nations, it is important to adapt relevant rules and regulations of organizations in government policies to easily plan activities at a lower level. This is to avoid lengthy procedurals and complexity of non-technical personnel to understand the importance of engineering works. A firm guideline and regulation should be circulated to conduct maintenance work regularly, and submission of bridge condition report timely for budget proposal in time will achieve a score of 4 and above.

[4] It is important to prepare a realistic maintenance plan along with experienced technical personnel and management teams to prioritize the work to utilize the minimum budget in the organization. A qualified and experienced technical personnel should be deputed to collect bridge condition reports to prepare maintenance plans either annually or half-yearly depending on the condition of bridges to achieve a score level of 4 above in this category of issue.

[5] Most developing countries lack good maintenance and management teams to monitor bridges on time to carry out maintenance work. Therefore, it is necessary to adopt a relevant BMS with a dedicated team to monitor the work on a regular basis to achieve level 4 and above in this category.

[6] Human resources comprise a technical person at the site and at the managerial level at the office to study the data coming from the site. The relevant training suited for the job should be provided through field attachment or internship before handing the complete charges to achieve level 4 and above.

Appendix

This is a summary of the data consisting of responses of each country report issues from year 2016 – 2020, Table A1 shows the responses of each country to the questions in the country report under area: "Issues to ensure budget for bridge maintenance and management".

Table A1 Issues to Ensure Budget for Bridge Maintenance and Management

Country	Issues to ensure budget for bridge maintenance and management
Afghanistan	Finding the best way to mobilize budgets Considering option to introduce transport tax system on expressways as potential source of budget Collection of fines from overloaded vehicles Improve budgeting for BM through training
Bangladesh	Grasp the priority of bridges that need to be repaired in Bangladesh and reduce unnecessary expenditure There is no separate budget for bridge maintenance and management.
Brazil	Economic recession caused bigger budget issue Manage large numbers of roads and bridges that greatly exceed available financial resources
Egypt	Issues that need to be prioritized over infrastructure maintenance, such as Egypt and education and health issues, have not yet been resolved. There is no problem with funds because there are several sources for ensuring the budget such as national income, transportation taxes and services projects on highways.
Guinea	Insufficient funds
Haiti	Bridge protection by rehabilitating upstream and downstream river banks
Liberia	Grasp the priority of bridges that need to be repaired Insufficient planning and organization, resulting in inappropriate budget allocation Most of the materials are imported from overseas and are very expensive Mobilize political support
Malawi	Find the best way to recover the budget and explore new sources of funding
Marshall Islands	There is no law on efficient maintenance and the budget allocation is not sufficient Lack of skills to manage budget
Mozambique	Insufficient funding
Nepal	Lack of technology for evaluating bridge conditions Shortage of contractors for maintenance Bridge maintenance is not included in the Strategic Road Network and Local Road Network Budget for construction and maintenance is consolidated under single unit
Palau	The budget is obtained from Congress separately from the Road Maintenance Fund.
Philippines	DPWH provides specific allocation of funds for bridge maintenance once a year
Samoa	Bridge maintenance budget is always included in the annual budget
South Sudan	Priorities are assigned according to the evaluation of bridge conditions, and the budget is allocated based on the priorities
Sri Lanka	Introduce the concept of giving priority to road maintenance There is no database for repair estimation Low Priority for bridge maintenance and lack of experienced staff No separately maintained central account for bridge maintenance
Sudan	After project maintenance studies and cost estimate, the request for fund is submitted to Ministry of Finance for approval and budget allocation
Tanzania	The annual budget for bridge maintenance and management accounts for 10% of the total funds provided for national road maintenance
East Timor	The contract system and budget set to maintain the bridge regularly for the rehabilitation of medium-sized bridges is determined by the calculation of damages

Togo	There is no problem with funds because funds can be borrowed from banks and other financial institutions
Uganda	Funds are allocated for the regular maintenance of the national road network and its operating expenses, so the bridge maintenance is also dependent on the funds
Vietnam	-
Cambodia	The schedule and system should be confirmed at the project planning stage in order to carry out the maintenance project effectively, the maintenance capacity of the responsible officer must be improved.
Democratic Republic of the Congo	Organizations must ensure budget control. Each department has its own budget. OEBK makes a living with money collected from tolls. There is no law for efficient maintenance and the budget is not sufficient. The Government is not yet able to provide sufficient means for the road maintenance The Roads Agency is not a commercial entity
El Salvador	Most of the budget allocated to the Road Conservation Fund is for routine maintenance of unpaved roads. The budget for the bridge maintenance program is included in the total budget for road maintenance.
Ethiopia	Correct bridge defects to maintain the functional and structural performance of the bridge ERA allocates budget for the priority of bridges that need to be repaired.
Myanmar	Determination of type of damage or deterioration Decision of repair method and reinforcement method Estimation of repair costs Request for bridge maintenance budget Insufficient fund for maintenance and management
Papua New Guinea	The final decision on financing depends on the government
Tunisia	The budget is insufficient to maintain all the roads and bridges
Zambia	BMS for prioritizing bridges has been developed, and maintenance costs estimation is performed automatically, and funds are allocated according to the results Once the maintenance needs are identified and cost estimate established, funds are allocated accordingly through the Annual Work Plan
Zimbabwe	The revenues distributed by Zimbabwean National Highway Administration and the Ministry of Finance to road authorities are not divided into budgets for road and bridge maintenance.
Bhutan	There is fixed annual budget for maintenance of bridges according to the number of bridges in the country
Cuba	Insufficient funding for the acquisition of equipment and materials for bridge repairs lack of qualified personnel to carry out the repairs of the bridges No organization in charge of infrastructure repairs
Honduras	Insufficient fund for maintenance and management There is a BMS, but not-updated. It is necessary to invest in knowledge and technology
Iraq	Sufficient funds for maintenance
Saint Lucia	Bridge maintenance and management has always been covered under road maintenance
Ghana	Insufficient fund for maintenance and management.
Indonesia	-
Laos	Insufficient fund for maintenance and management.
Nicaragua	-
Ukraine	The main source of financing for maintenance and management of bridges of state roads of general use is State Road Fund. Repairs and maintenance of bridges are also funded by local budgets.

Table A2 shows the responses of each country to the question under " Issues of technical level of bridge inspection ".

Table A2 Issues of Technical Level of Bridge Inspection

Country	Issues at the technical level of bridge inspection
Afghanistan	There is no reference inspection method, inspection procedure, inspection equipment, data and database.
Bangladesh	There is a fundamental problem in the current bridge maintenance guidelines. Don't have proper training and guideline how to inspect the Bridges. There is a lack of available tools/equipment for inspection of bridges.
Brazil	I do not know the inspection procedure for the bridge.
Egypt	Incorrect Schmitt hammer test results. The issues are state of steel and concrete; inspect welding, substructure and super structure, find erosion of steel, cracks in concrete.
Guinea	Lake of equipment.
Haiti	There is no equipment to evaluate bridges properly.
Liberia	Bridge inspection has not been implemented.
Malawi	Bridge inspection is performed visually, and when a problem is deemed to be serious, a detailed analysis is performed on the problem and a consultant is invited to derive a solution.
Marshall Islands	Insufficient inspection equipment, inspection methods, and high-level inspection skills.
Mozambique	Need Technical experts in larger, complex, and more sophisticated multi-span bridges.
Nepal	The increasing number of bridges constructed every year, the number of technical staffs has to be increased so that inspection and maintenance of bridges can be done as specified by the guidelines. The guidelines developed for the inspection and maintenance of bridges needs to be updated.
Palau	-
Philippines	Non-destructive inspection equipment was introduced only at the regional offices; all DEOs must be equipped with this type of equipment because the DEO's bridge inspectors perform annual inspections. Inspectors need orientation & trainings related to the Standard / Guideline.
Samoa	LIA has a shortage of staff and relies on private consultants. Lack of inspection and routine maintenance.
South Sudan	The outline of the list of inspected bridges is not enough. Initial assessments: review and evaluation of the periodic Inspection. Intermediate assessment: assessment of detailed survey result.
Sri Lanka	Lack of human resource for inspection. It takes a considerable amount of time to complete the bridge inspection. Preliminary inspection methods such as pole cameras can be used at inspection sites where no one can enter. No sufficient training in order to carryout bridge inspections.
Sudan	Limited guideline for inspection.
Tanzania	Need employ experienced staff. Some bridges are high and require cranes. There is no advanced equipment for non-destructive testing and deflection measurement of bridges.
East Timor	No customs inspections have been conducted.
Togo	It is difficult to evaluate the inspection results of bridges. There is no reliable database. There is no research institution specializing in bridge inspection. There is no specific guideline of bridge inspection.

Uganda	The number of staff with professional bridge inspection skills is limited due to specialized training required. There's limited experience in bridge maintenance among the staff. Limited availability of required inspection tools like inspection vehicles, crack gauges and detectors, specialized cameras, among others. Lack of standard for bridge inspections, low budget and lack of a complete bridge inventory.
Vietnam	-
Cambodia	The experience and expertise of personnel performing the tests are still limited. The equipment is not appropriate. There is no non-destructive inspection equipment. Insufficient manual for bridge inspection.
Democratic Republic of the Congo	Regarding bridge inspection, there is no problem because of the high technical level thanks to experience and appropriate equipment. Lack of financial means Lack of material means Lack of human resources.
El Salvador	Poor security and gangs dominate where there are many bridges, and do not permit performing inspections. Insufficient skills and qualifications of inspection technicians.
Ethiopia	Bridge inspection is conducted only visually, and no modern technology has been introduced. Scarcity of skilled inspection.
Myanmar	Skills and qualifications of inspection technicians Knowledge of instrumentation equipment and performance Insufficient or lack of inspection equipment, reinforcing technologies and inspection vehicles.
Papua New Guinea	Due to the lack of experienced local expertise in the countryside, staff in the design department emphasize that not all requirements are being met as expected. Technical experts are currently working on the support and training of local officers.
Tunisia	Both government and private consultants have no experienced and excellent staff in bridge inspection. The ministry lack the necessary equipment for the inspection, and lack of the expert in the ministry.
Zambia	Limited financial resources also limit the technical level of bridge inspection. Lack of equipment for inspection.
Zimbabwe	Bridge inspection is performed once a year, but depending on the nature of the defect, the integrity of the structure, and the type of vehicles that use the road, the inspection frequency may be high.
Bhutan	Lack of equipment for inspection and technical experts
Cuba	-
Honduras	The standard for bridge inspection (old standard) is necessary to review and update.
Iraq	There is no regular Bridge Maintenance System (BMS).
Saint Lucia	Insufficient engineer within the ministry trained specifically in bridge design and maintenance.
Ghana	Lack of continuous training for the Bridge Inspectors Inadequate funds (budgetary allocations) Lack of adequate Inspection Kits Lack of experience in carrying specific Inspection (e.g: underwater bridge foundation Assessment).
Indonesia	There is limited access to observe elements that determined for inspection in the guidelines. Lack of experience in carrying specific Inspection.
Laos	Not enough experience technical staff and equipment for Bridge inspection, especially equipment for under water inspection and etc.
Nicaragua	Basic level in performing bridge inspection.
Ukraine	Not enough specialized organizations and certified specialists in Ukraine to inspect and check bridges in Ukraine.

Table A3 shows the responses of each country to the questionnaire " Issues of maintenance and management (organization, budget, institutions)" in the country report.

Table A3 Issue of Maintenance and Management (Organization, Budget, Institution)

Country	Maintenance issues (organization, budget, institution)
Afghanistan	Bad security There is no experience of technicians or high-quality machines
Bangladesh	There is no priority for bridges Insufficient budget for maintenance Insufficient capacity of RHD (organization performing maintenance) Lack of available tools/equipment for inspection of bridges
Brazil	SETRAN operates only when a problem occurs in the bridge
Egypt	Sufficient budget. GARBLT in cooperation with consultant office are inspecting bridges and determine the repairs required as well as budget.
Guinea	Bridge maintenance service does not exist now
Haiti	Insufficient funds
Liberia	Bridge inspection has not been implemented
Malawi	Repair work is supervised daily by consultants and supported by technical teams Funds are raised according to the level of maintenance
Marshall Islands	The budget allocated to bridge maintenance ($ 15,000 per year) is set at about 1.4% of the total construction cost of the project (about $ 11,000,000).
Mozambique	ANE has begun introducing a bridge management system that improves all issues related to bridge maintenance, but it is rarely used There is no specific budget allocation for maintenance and the budget available is used for activities under Road and Bridge Maintenance
Nepal	Organization: Department of Roads Separate Budget Sub-head for Maintenance, Rational Allocation of budget Institution: Research, Innovations and Development in DoR
Palau	-
Philippines	No specific section/team under maintenance division that deals and focuses with bridges only
Samoa	LTA is the only agency that manages bridge maintenance and bridge repair plans, and the number of people is insufficient
South Sudan	Although the priorities of the bridges have been set, the budget is too small to maintain and maintain the bridges sufficiently Technical Advisory, Legal Advisor, Directorate of planning and policy formulate
Sri Lanka	Maintenance and management of the lower part of the bridge is problematic No dedicated unit for bridge management in Road Development Authority Technical capacity needs to be improved Lack of human resources
Sudan	Organization: National Highway Authority Budget: National Budget
Tanzania	Work load for Emergency works, preventive measures and urgent works are carried out by single organization The budget provided by the government is small. Large scale of network for institutions is required proper management
East Timor	No customs inspection.
Togo	Lack of local companies capable of maintaining bridges Lack of qualified staff
Uganda	Because existing BMS cannot evaluate the deterioration of bridges, long-term needs cannot be predicted Organization: Uganda National Roads Authority (UNRA) Budget: 462,464 USD Institution: Responsible UNRA Maintenance Station (area station) Under the Directorate of Road Maintenance. Lack of equipment and fully trained personnel.
Vietnam	-

Cambodia	Organization: Lack of human resources and experts Budget: Budget constraints are severe Institution: Lack of human resources and experts
Democratic Republic of the Congo	Ineffective process of approving request for necessary equipment Lack of financial means Lack of material means Lack of human resources
El Salvador	Large budget is the biggest problem FONDO DE CONSERVACION VIAL does not have specialists in bridge maintenance management
Ethiopia	Organization: Ethiopian Road Authority Budget: Ethiopian government Institution: Ethiopian Road Authority
Myanmar	The Bridge Maintenance Division received a budget of $ 12 million in the 2016 budget, which is used for bridge repair, reinforcement, maintenance and repair projects nationwide The Budget is insufficient to maintain the bridges and the roads
Papua New Guinea	Lack of funding is always a critical issue
Tunisia	Insufficient experienced staff in this area The Budget is insufficient to maintain the bridges and the roads
Zambia	Limited financial resources and the lengthy procedures for performing work The maintenance budget for 2020 was USD 1,096,047.52 Maintenance of bridges is still new concept and technical know-how on maintenance methods is limited
Zimbabwe	Bridge maintenance units were once established in each state, but they were all released due to resource constraints
Bhutan	Organization: Department of Roads Budget: the lack of technical knowledge of budget focal persons the budget divisions and insufficient budget Institution: Bridge Division
Cuba	-
Honduras	The greatest investment and attention is on roads. There is minimal attention in bridges
Iraq	Bridge inspection has not been implemented
Saint Lucia	The development of the Bridge Maintenance and Management Program is currently in progress. It has not yet been implemented.
Ghana	Organization: outsourced because lack of capacity. Budget: funds are not release on time for the works. Institution: outsourced because lack of capacity.
Indonesia	The procedures and criteria for prioritizing the use of fund allocations for bridge maintenance and rehabilitation compared to road maintenance work in a road network system are not yet complete There are limited personnel who can review the results of bridge maintenance and rehabilitation design work carried out by private consultants
Laos	Organization: Not enough experienced staff to implement the bridge inspection, evaluation and monitoring of the maintenance of bridge Budget: Insufficient budget Institution: Lack of institutions for analyzing of the bridge management and maintenance
Nicaragua	Organization: Ministry of Transportation and Infrastructure Budget: Budget is variable depending on the needs identified in the different regions of the country, the highest priority was taken into consideration. Institution: Consortium of state companies
Ukraine	Insufficient number of specialized organizations

Table A4 shows the responses of each country to the questions in the country report, " Issues in preparation and implementation of bridge maintenance and management plan".

Table A4 Issues in Preparation and Implementation of Bridge Maintenance Plan

Country	Issues in Preparation and Implementation of Bridge Maintenance Plan
Afghanistan	-
Bangladesh	It is necessary to secure appropriate funding sources for bridge maintenance Preparing a Bridge Maintenance Manual
Brazil	There is no maintenance plan due to lack of human resources and budget
Egypt	Budget restrictions are severe There are few effective consultants Few contractors apply the maintenance plan
Guinea	A bridge maintenance plan has not been formulated.
Haiti	-
Liberia	-
Malawi	Consultant or bureau technician prepares tender documents for contractors, decides and executes budget for maintenance work.
Marshall Islands	Lack of technical skills to develop a stable maintenance plan.
Mozambique	Lack of political support. Priorities are given to building new structures than on maintaining existing ones
Nepal	The budget head for bridge construction and bridge maintenance is the same in Department of Roads Necessity of enhancement of capacity of technical personnel with trainings, workshops, etc.
Palau	-
Philippines	The bridge maintenance management plan is based on the results of bridge condition surveys under the bridge management system Do not have maintenance and management plan specifically for bridge
Samoa	Samoa is implementing a maintenance plan for the local Samoa Bridge (SBMMP) Bridge maintenance and management plan in Samoa was nonexistent in the past and is currently pending
South Sudan	Create a traffic management plan for bridge inspection Bridge inspectors need to collect data on missing bridges, such as drawings of existing bridges and newly constructed bridges, determine whether to repair the bridge, and create a bridge maintenance plan
Sri Lanka	Because the work staff of the project is limited, considerable labor is required Because existing data has some errors, it is necessary to collect data again Collecting and feeding of inspected raw data in to the Bridge Data base System. Because all the available data was in hard copied mode and also not up to date. No bridge maintenance manual or management plan for RDA and Lack of bridge experts.
Sudan	There is no comprehensive plan
Tanzania	There are few skilled staffs to carry out bridge maintenance Bridge priority Insufficient fund allocated for Bridge major repairs and preventive works Lack of sophisticated equipment for carrying out bridge maintenance
East Timor	-
Togo	The field of bridge maintenance is still in its infancy, and considering budget constraints, there is no actual bridge maintenance plan
Uganda	Lack of motivated and dedicated skilled staff to implement the plans Lack of inspection data for bridges to make maintenance plans. Insufficient budget Still developing, updating bridge inventory and preparing bridge maintenance plan.
Vietnam	-
Cambodia	Budget constraints-Lack of human resources and experts.

Democratic Republic of the Congo	The OEBK conducts inspections that enable observation of the deterioration state at the site, and makes it possible to evaluate the deterioration state Lack of financial means Lack of material means Lack of human resources
El Salvador	The plan is based on damage compensation only, and does not take into account the importance of the bridge, type of damage, location, repair cost, etc.
Ethiopia	Emergency of database systems that generate experts in small and large bridge maintenance needs to be a top priority Little awareness and knowledge on the need for in-advance repair of bridges Lack of skilled technical person
Myanmar	There is no bridge maintenance plan at present, and we must set up a bridge maintenance system in the future The main issue is a finical problem
Papua New Guinea	Due to financial constraints, not all work is performed as planned
Tunisia	Lack of material and human means There is no implementation agency Administrative complexity associated with chart expansion Lack of drawing as built for all the bridges
Zambia	There is not enough data to formulate a maintenance plan Insufficient funding to perform certain required tasks Long-term procurement procedures Support is being provided only for the construction of new bridges Limited resources are available for implementation Routine bridge maintenance projects were recently started so there are very few contractors who have the much-needed experience in bridge maintenance
Zimbabwe	Inability to hand over to appropriate young staff
Bhutan	Lack of enough budget in the government for proper planning and execution. Fails to propose reliable and research based maintenance and management plan to higher authorities for approval and sustainable budget Lack of skilled technical person
Cuba	-
Honduras	Higher priority is required to address bridges. It is necessary to have an updated BMS, prioritize according to results, and act following an appropriate plan
Iraq	There is no plan for bridge maintenance & management
Saint Lucia	The Bridge Maintenance and Management plan has not been implemented
Ghana	Lack of Data collection, proper storage and their accessibility No periodic training of the staff to manage the bridge data Non-availability of Computerized system to analyze and prioritize bridge maintenance programs. Internal and Political interferences Budgetary allocation Inadequate Capacity of Local Contractors in Bridge Maintenance Works
Indonesia	The Bridge Maintenance and Management plan has not been implemented
Laos	-
Nicaragua	Lack of financial means Lack of equipment and technical methodology to perform a detailed analysis Lack of technical capacity in inspection and evaluation of damage to bridges
Ukraine	Funding limits

Table A5 shows the responses in each country to the questions in the country report, “Issues of introduction of BMS (work load for data input, update of data, technical level, maintenance of BMS, collaboration of daily work etc.,)”.

Table A5 Issues of Introduction BMS

Country	Issues of BMS introduction (work load for data input, coordination of daily work, etc.)
Afghanistan	Creating an appropriate BMS requires the experience of a technician and strong economies Rarely do research on systems throughout the country The system used is not uniform, and there is no specific system throughout the country
Bangladesh	The sustainability of BMS is important HRD staff training is required The ability to allocate funds based on BMS results is required
Brazil	BMS has not been developed
Egypt	The work environment (office) is not specialized in BMS and is not efficient It is difficult to apply all elements of BMS due to the nature of the site Collecting data about bridges, putting maintenance plan also their costs
Guinea	BMS has been developed but implementation is still lacking
Haiti	BMS sustainability is an issue
Liberia	BMS has not been developed
Malawi	BMS is not installed
Marshall Islands	Data input is computerized
Mozambique	The system has not been fully updated, the aim of the Government is to mobilize resources and all the necessary logistics to conduct a comprehensive survey trough all bridges to update the data in to the BMS
Nepal	Insufficient technical human resources within the organization Lack of human resources with skills for condition assessment Lack of a minimum training program for BMS technical staff Lack of motivation According to the government's view, the priority of bridge maintenance is low Work load for data input is distributed to the field level implementation offices R&D
Palau	-
Philippines	DPWH established BMS in 2003 under road information and management Bridge data is collected annually based on bridge inventory and condition surveys Bridge Management System (BMS) was introduced to DPWH-ARMM but it was not used and implemented until now
Samoa	All bridges are registered with the Samoa Asset Management System (SAMS), and record their width, span, type, location, etc.
South Sudan	Conduct bridge evaluation Procedure must exist to that data be updated in two instances. (1) After a bridge inspection. (2) At the completions of a project
Sri Lanka	All bridges need to be inspected and recorded, including details of defects, which significantly increases the data entry workload It is difficult to update computer data A data securing system is needed
Sudan	There is no BMS
Tanzania	It is difficult to repair because there are several bridges designed overseas The design programs used for design are not common to Tanzania TANROADS is operating the BMS as a tool for keeping bridge data, planning and for implementation of bridge programs
East Timor	-
Togo	BMS has not been developed yet
Uganda	Workload for data entry increased Update of data: Usually just before and after principal or special inspections or repairs have been undertaken Technical level: Few dedicated skilled staff Maintenance of BMS: Few staff members can maintain BMS Collaboration of daily work: Difficult of collaborate since maintenance stations may not have direct access to the current BMS software KCCA is in the process of developing its BMS
Vietnam	-

Cambodia	To manage, maintain and repair bridges in Cambodia | EXMID was newly established in 2016
Democratic Republic of the Congo	Sustainability of BMS Staff training is required
El Salvador	There are few problems with system introduction
Ethiopia	The workload for data entry is large and the number of staff is insufficient Data is updated twice a year by consultants The technical level of BMS is low Scarcity of skilled manpower in bridge maintenance and inspection Lack of interest from engineers to work in BMS
Myanmar	Because BMS is still under development in Myanmar, it is necessary to study from a technologically advanced country like Japan Bridge Inventory & Technical issue. (software for input data records)
Papua New Guinea	The data entry process is performed at the headquarters and managed centrally, so only headquarters officers can access the on-site systems Data updates are also performed by headquarters executives, and in the current situation of financing, most data cannot provide the required information
Tunisia	Lack of detailed information on old bridges
Zambia	Because the skills of staff handling BMS are limited, it takes a long time to input and verify data provided by an external consultant Since the software used is protected by copyright, license fees must be paid on a yearly basis Some bridges cannot be inspected due to impassability during the condition survey More staffs need to be trained in BMS use and the workload for data input is the responsibility of the consultant The adoption of the BMS by the users and the update of the survey data is slow
Zimbabwe	The system developed by the IT department is in the prototype stage. At present, data from old manual document files is being collected The main issue is lack of funds for implementation of BMS, data collection on site, and lack of appropriate equipment for bridge inspection
Bhutan	BMS has just introduced from JICA and is slow system. It takes time to operate and load any information from system The technical level of BMS is insufficient Shortage of manpower to collect data
Cuba	The BMS, attempts have been made to apply it, but execution has not been consolidated in practice
Honduras	BMS called HONDUSAP was created in 1997 and has not updated (Last update in 2006)
Iraq	BMS has not been developed yet
Saint Lucia	The BMS is currently being developed and overall, it is based on a robust visual data collection program
Ghana	Bridge Division used to have a Data Management System – Bridge Maintenance Management System (BMMS) which is no more functioning JICA is currently running a capacity building program for the Ministry of Roads and Highways (MRH) and its Agencies. Under this program the Bridge Management System (BMS) will be sourced
Indonesia	Validating input data in real-time There has been no maintenance of BMS at all since 1992
Laos	BMS has been developed but its implementation is still lacking No inspection Records
Nicaragua	Work load for data input: It is done directly in a single order that is intended for the administration of data base within the bridge office The system has not been updated since its introduction to the date The technical level is empirical level, there is no constant training related to this topic Incompatibility with new computer systems, lack of functionality of some tools, outdated technical information and complementary bridges
Ukraine	The AEBSM database is not fully implemented at this stage, given the limited financing of the road industry

Table A6 show the responses of each country to the questions in the country report, " Human resources at Planning level " and "Human resources at inspection and repair work".

Table A6 Human Resources at Planning Level and Human Resources at inspection and Repair Work

Country	Planning-level human resources and human resources at inspection and repair work
Afghanistan	-
Bangladesh	Currently, the organization that is planning road maintenance is working under the bridge management building, and it is necessary to ensure smooth communication between these two zones. Bridge Management Wing (BMW) of RHD. Local staff must be trained on bridge inspection and repair work Contractors must be trained in certain repair work before work instructions are issued Departmental labor forces or by outsourcing.
Brazil	There is one civil engineer in the arts department and one civil engineer in the transportation infrastructure plan There are two civil engineers
Egypt	A professional consulting firm that studies maintenance methods General authority for roads, bridges and Land Transport staff GARBLT professional staff and consultant for initial inspection and repair
Guinea	It is conducted as a national business Made as a local government project
Haiti	Work with local staff to plan work to be performed according to the amount available Government engineers, government topographers, surveyors and inspectors supervise the repair work
Liberia	-
Malawi	Planning is performed by the planning and design department, and facilities to deal with all problems are set up Inspection work is being carried out by road authority inspectors during road condition surveys The human resources are sufficient
Marshall Islands	The Project Management Department is in charge of project and information management, and also has responsibility for budget The Road Division is in charge and there are enough people
Mozambique	Performed by 44 technicians Road network management department – 5 Technician Planning and Budget department – 4 Technician Cooperation department – 3 Technician A group of seven engineers is being trained to conduct bridge surveys and inspections nationwide Repair works are awarded to contractors through competitive bidding. The supervision of works is executed by private consultants
Nepal	Bridge maintenance adjustment section Design and monitoring department A bridge in the project area (4 locations) Bridge Division at DoR has 12 technical officers Maintenance Cooperation Unit has 3 engineers Main inspections are usually performed by a qualified bridge engineer, either from a consultant or the Bridge Branch; there are a total of 34 DROs, | each DRO has one senior section engineer, 5 to 8 engineers, there are 10 to 16 sub-engineers There is no such provision for dedicated technical personnel for the bridge inspection and repair works in the Road Divisions and Bridge Division The inspection job is done by outsourcing
Palau	-

Philippines	Bridge inventory and condition survey are carried out annually by a bridge inspector (BI) who is accredited by the district office Multi-tasking is practiced due to shortage of manpower Regular maintenance of bridges along national roads is under the supervision of all DEO maintenance sections, and maintenance crews perform regular maintenance work Multi-tasking is practiced due to shortage of manpower
Samoa	LTA has only limited knowledge of engineers and most of them rely on outsourcing Small number of people rely on outsourcing
South Sudan	Human resources planning level may be done at different level and for Purposes. (national level, sectoral level, industry level, units level and departmental level)
Sri Lanka	JICA's team of experts is working with local engineers on planning under the model projects of the three provinces In RDA bridge design division & planning division Technicians work in nine states for the inspection process starting with model projects, but no group has been trained for repair work Deputy directors & senior engineers for inspections
Sudan	National Highway Authority technical staff for planning National Highway Authority technical staff for inspection
Tanzania	Planning engineer Bridge engineers Inspector Monitoring management team Bridge engineers Inspectors Contractor/Sub contractor team
East Timor	It is not necessary to strengthen technical staff to carry out work Little experience in job analysis
Togo	The Road Data Bank Management Department (DBDR) is composed of one civil engineer, two technicians, one accountant, and one secretary Staff of the General Directorate of Public Works (DGTP) composed of civil engineers and technicians
Uganda	4 staff members: One (1) Manager - Network Planning, Three (3) Engineers/ officers-Network Planning Director, deputy director roads management, the supervisor bridge maintenance and officer bridge maintenance 1 to 2 repair staff, 1 to 3 maintenance technicians, 2 to 4 workers Both the supervisor and officer bridge maintenance with the officers for roads and drainage maintenance do inspections
Vietnam	-
Cambodia	It has not been decided 5 workers
Democratic Republic of the Congo	Director Manager 3 engineers and 3 technicians Provincial Direction of office of Urban Roads and Drainage (OVD) in Kinshasa (DPK)
El Salvador	12 general managers and managers, 15 bridge management and road inventory sections, 8 statistical monitoring sections, 4 environment sections, 15 engineering departments, 30 real estate acquisition and involuntary resettlement sections (84 in total) 1 planning manager and 7 project planning specialists 6 managers, 6 independent quality assurance departments, 7 R & D sections, 21 soil material sections (40 in total) Twenty-four (24) inventory inspectors, in charge of the inspection of the state of bridges nationwide
Ethiopia	There are two consultants and three clients from each district The number of human resources at the time of inspection is two from consultants in each district and one from clients (Ethiopian Road Authority)

Myanmar	We plan to upgrade the capacity development of department engineers At planning level from Director General to Deputy Director Level not too much difference in gender description, Male are 70% and Female are 30% Receive short- and long-term training both domestically and abroad At inspection and repair work has gender description
Papua New Guinea	In the planning stage, with the support of the consultants engaged, standards and standards for various types of repair categories, such as small, large, reconstruction Planning work is being performed according to the specifications Small-scale repairs are performed using day labor, and most large-scale repairs, reconstructions, and emergencies are performed with the assistance of contractors and consultants
Tunisia	The plan is guaranteed by the road exploitation and maintenance department The Program, Planning and Monitoring Department has three person Visual inspections are performed by both regional and development / repair engineers Detailed inspections are guaranteed repair work by private consultants and private contractors
Zambia	The bridge construction, management and repair plans are performed by the bridge section of the RDA's Planning and Design Bureau. The bridge consists of six engineers, and is led by senior managers who supervise all activities in the department Inspection, repair and emergency response of bridges are performed by the bridge maintenance department of the Road Maintenance Bureau, and bridge construction is performed by the RDA Construction and Repair Bureau Principal Engineer X2 (one from Planning and one from Maintenance Dept. at HQ) Senior Engineer X10 (one from each Regional Office) Engineer X11 (One from each Regional Office and one from HQ) Technicians who are based at Regional Offices carry out repair work.
Zimbabwe	Bureaus have the human resources to carry out planning, inspection and repair work, but they need to be equipped with the latest appropriate technology Bureaus have the human resources to carry out planning, inspection and repair work, but they need to be equipped with the latest appropriate technology
Bhutan	Performed by Department of Road is supported by four divisions and nine regional offices All the technical issues and bridge planning is carried out by the Bridge Division centrally located in the Department. Therefore, Human Resources capacity of the division will have to carry out the inspection and repair work along with the site staff of the Regional Office
Cuba	- 1 mayor per municipality throughout the country for inspection
Honduras	The Ministry of Infrastructure and Public Services develops the maintenance and management of bridges through the planning, evaluation, and management department The human resource in inspection and repair work is minimal. When it is necessary to carry out inspection work on one or more bridges, as well as repair work, the government hires consulting services
Iraq	-
Saint Lucia	The BMS is still being developed, therefore this has not yet been established
Ghana	Managers and Directors Civil Engineering with a minimum of 3 years working experience and Graduate member of Ghana Institution of Engineers
Indonesia	Engineers Bridge Inspectors can be graduate engineers and expertise
Laos	The RAD engineer and Provincial Public work and Transport Division who has responsibility for planning level and some time we are employs the consultant to assist For National road is done by RAD engineer and Provincial PWT, the Local road is done by Provincial and District PWT
Nicaragua	The Ministry of Transportation and Infrastructure, within its organization, has a bridge office where there are three engineers in charge of planning the inspection of bridges The General Planning Division and the repair General Directorate of Road

Ukraine	The State Road Agency of Ukraine Road Maintenance Department There is absence of fully specialized organizations and certification specialists in Ukraine

CHAPTER 5

Conclusion and Recommendations

5.1 Conclusion

Bridge Maintenance and Management (BMM) in Laos and many developing countries consist of many issues requiring improvement and upgrade. In Laos and many developing countries, issues of BMM are not collected, and much data and information of BMM are not disclosed on the internet. Thus, chapters 2 of this thesis summarized the current status and raise the significant issues of the road (bridge) maintenance and management in Laos has many issues that require improve and upgrade, such as: 1) Data related issues are lack of data, statistics and condition information. And RMS (and BMS) will be effective when there is enough data collected & analyzed; 2) Budget related issues MPWT (Laos Govt) should pay much attention to RMS, to allocate the budget adequately and efficiently. And issues in unit price of road construction and maintenance works; 3) Human resource related issues are difficulties to allocate suitable personnel in charge of management and maintenance due to frequent and unpredictable personnel shifts; 4) Technical and design related issues (current designs do not consider) details to prevent damage in each parts of bridge. And facilities to make inspection work easier.

In chapter 3, a total of 53 causes of delays are identified as important in road construction projects in Laos. The important delay causes are classified in eigth groups, the result by combined view there are 8 delay causes in high impact level, and 5 causes in very high impact level.

Chapter 4 demonstrates the various issues related to BMM tasks from country reports data received from total of 102 trainees coming from 42 developing countries and participated in Japan International Cooperation Agency (JICA) training courses during the period 2016-2020, is collected and reviewed.. The current status was analyzed in six main issue areas, including budget issues, technical level issues, issues of maintenance and management, issues related to bridge maintenance plan; issues related to bridge management system (BMS); and human resource issues. Then Transport Asset Management(TAM) maturity model concept is used to assess the relative position of each agency for TAM processes, i.e., operating, maintaining, upgrading, and expanding physical assets effectively throughout their life cycle. The five-level maturity scale can be used to understand the agency's position on a wide range of TAM practices and is used throughout this guide. Level 1 "Initial"; Level 2 "Awakening"; Level 3 "Structured"; Level 4 "Proficient" and Level 5 "Best Practice". The results of level average are almost in level 2 or 3. However, both 1) level in issues of the technical level of bridge inspection, and 2) level in issues in preparation and implementation of bridge maintenance planare mostly in level 1 or 2.

5.2 Recommendation

To solve the issues mentioned above, the ways that can prevent and solve such issues and highlight important reasons that should be treated as soon as possible such as bellowing:

- Laos government should focus investment on collecting & analyzing inspection data to be used in RMS.
- Based on data, priorities of maintenance should be set to suit roads and bridges conditions, and increase both convenience and safety of road users.
- Such data helps in proper budget management too.
- To increase the efficiency of Human Resources (HR), regular training is required for all positions. Moreover, HR management guideline is required to prevent disturbing personnel changes.
- To improve efficiency of inspection & maintenance works besides to infrastructure longevity, it is advisable to seek help from developed countries which have experience in this area.
- Necessary future work is to use the severity index of delay causes as a baseline for improving rules, agreements, management, administration and planning.
- The modified processes should be tested and used, then checked against percentage delays to verify effectiveness. This process should be iterated to improve project implementation process.
- Based on the results of RAM, we know which issues need more focus and improve in Laos. Other developing countries with higher RAM maturity levels than Laos, can be used as models to solve issues in Laos.

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