Ministry of Works and Transport
The Republic of Uganda

ADVISOR FOR CAPACITY DEVELOPMENT IN ROAD CONSTRUCTION AND MAINTENANCE IN THE REPUBLIC OF UGANDA

FINAL REPORT

JUNE 2023

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

YACHIYO ENGINEERING CO., LTD.

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Project Location Map

Photographs

Kick-off Meeting
JICA Project Team explained the draft of Work Plan and discussed with participants from MoWT.

C/P Meeting
Following the kick-off meeting, JICA Project Team and focal counterpart from MoWT had a technical discussions.

TOT at NVTC
JICA Project Team conducted the basic course in the TOT in collaboration with Nakawa Vocational Training Center (NVTC) and all the programme at NVTC was successfully completed.

Basic Course at NVTC
JICA expert provided a lecture on electronics together with the instructor from NVTC.

Reporting Session of Self-training
At the beginning of each field work, a workshop was held to report the results of the self-training by TOT members. TOT members prepared presentation materials and reported on their activities.

TOT at Bugembe Regional Mechanical Workshop
In order to confirm the achievement of TOT, TOT members themselves provided an educational training to MoWT mechanics. The photo shows a lecture on how to use measuring equipment at the Bugembe Regional Mechanical Workshop.

Practical Training

At the machining shop of MoWT Workshop, JICA expert provided technical guidance on how to process and repair engine cylinder block liners.

Practical Training

Practical training on how to disassemble, measure, and assemble small engines as well as educational methods was conducted at the Kampala Central Mechanical Workshop.

Advanced Course on Compaction Equipment

TOT was conducted in collaboration with local dealers. The photo shows the instruction of the hydraulic pressure measurement method using the actual equipment.

Advanced Course on Heavy Equipment

TOT was conducted in collaboration with local dealers. The photo shows a lecture by JICA expert on the maintenance theory and precautions for the excavator.

Joint Workshop between both civil and mechanical team

The civil team and the mechanical team held a joint workshop. Participants had discussions to work together for an effective use of the GPS tracking system of equipment.

Closing Ceremony

Group photo after the closing ceremony of the Project.
TOT members received the training completion certificate at the ceremony.

Abbreviations

AC	Assistant Commissioner
BMAU	Budget Monitoring and Accountability Unit
CE	Civil Engineer
CME	Chief Mechanical Engineer
CMES	Commissioner Mechanical Engineering Services
CW	Central Workshop
DEW	Director Engineering and Works
DEW/EIC	Director of Engineering and Works/Engineer in Chief
DRRU	District Road Rehabilitation Unit
FA	Force Account
FY	Fiscal Year
GPS	Global Positioning System
ITISPR	Integrated Transport and Infrastructure Services Programme Review
JBIC	Japan Bank for International Cooperation
JICA	Japan International Cooperation Agency
KCCA	Kampala Capital City Authority
ME	Mechanical Engineer
MoFPED	Ministry of Finance, Planning and Economic Development
MoWT	Ministry of Works and Transport
MSI	Mechanical Services Inspection
MSO	Mechanical Services Operations
NVTI (NVTC)	Nakawa Vocational Training Institute (Nakawa Vocational Training College)
OJT	On the Job Training
PS	Permanent Secretary
PXE	Principal Executive Engineer
RMW	Regional Mechanical Workshop
SE	Senior Engineer
SME	Senior Mechanical Engineer
TOT	Training of Trainers
ULGA	Uganda Local Government Association
UNIDO	United Nations Industrial Development Organization
UNRA	Uganda National Roads Authority
UR	Urban Roads
WM	Workshop Manager
ZE	Zonal Equipment
ZC	Zonal Centers

Chapter 1. Outline of the Project

1.1 Background of the Project

In August 2019, the Government of the Republic of Uganda (hereinafter referred to as Uganda) submitted a request to the Government of Japan for technical cooperation aimed at improving the policy making and planning capacity for road construction and maintenance managed by the Ministry of Works and Transport (hereinafter referred to as MoWT), improving road construction and maintenance systems, developing human resources for the proper utilization of road equipment. In response to this, the Japan International Cooperation Agency (hereinafter referred to as JICA) decided to dispatch a technical expert team (hereinafter referred to as the Project Team or the Expert Team or the Team) to implement the Technical Cooperation (hereinafter referred to as the Project).

1.2 Objective of the Project

The Project implements technical assistance for the staff in charge of road construction and maintenance and of managing road maintenance equipment owned by MoWT in order to improve their capacity in the field of road construction and maintenance.

Table 1-1 shows the project goals, expected outcomes and outline of activity.

Table 1-1 Project Goals, Expected Outcomes and Outline of Activity

Project Goals	MoWT personnel improve their capacity in the fields of road construction and maintenance.
Expected Outcomes	Outcomes 1: Improvement measures for policy making, planning, and budgeting for road construction and maintenance of MoWT are proposed. Outcomes 2: A system for road construction and maintenance, including effective use of road construction equipment, of MoWT is improved in visible achievement of proper road construction/maintenance works for fair/good conditions. Outcomes 3: Capabilities of MoWT's road engineers, operators and mechanics through road construction/maintenance and use of equipment is strengthened.
Outline of Activity	Activity 1-1: To evaluate and analyze current systems for policy making, planning and budgeting related to road construction and maintenance, then to advise and recommend areas for improving the system. Activities 2-1: To assess and analyze current systems for road construction and maintenance including effective use of road construction equipment, then to train and advise for improving the system. Activity 3-1: To evaluate and analyze current issues of human resources, such as road engineers, operators and mechanics, in charge of road construction and maintenance, and the current status of equipment use/management, then to train and advise personnel for the appropriate utilization and management of equipment. Activities 3-2: To develop a future improvement plan based on the issues identified through Activities 3-1 above.

1.3 Members of the Project Team

The members of the Project Team are shown in Table 1-2.

Table 1-2 Members of the Project Team

Name	Organization	Assignment
Isao TAKAHASHI	Yachiyo Engineering Co., Ltd.	Team Leader / Road Management Plan： ➢ Project Management ➢ Assistance for improving the capacity for policy making and planning for road construction and maintenance ➢ Assistance for improving road construction and maintenance systems
Makoto SUGIYAMA*	Yachiyo Engineering Co., Ltd.	Road Construction/Maintenance Equipment Management： ➢ Technical assistance for proper utilization of road equipment

Note: * In the 2nd field work, Mr. Makoto SUGIYAMA replaced his predecessor Mr. Etsuo HASHIGUCHI.

1.4 Implementation Schedule

The field work schedule of the Project is shown in Table 1-3.

Table 1-3 Implementation Schedule

Year/Month	2021			2022											2023				
	4	5	･･･	･･･	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5
Team Leader / Road Management Plan：Isao TAKAHASHI																				
Road Construction/Maintenance Equipment Management：Makoto SUGIYAMA	1st Field Work				2nd Field Work				3rd Field Work					4th Field Work				5th Field Work		

The Project Team conducted the five field works in Uganda as specified as follows:

1st Field Work

Explaining, discussing and finalizing of the work plan, analyzing actual capacity and issues of MoWT, commencing a training programme, etc.

2nd Field Work to 4th Field Work

Interim feedback, conducting OJT (On-the-Job-Training), holding a workshop, interim evaluation, etc.

5th Field Work

Interim feedback, conducting OJT (On-the-Job-Training), holding a workshop, final evaluation, advising an improvement plan, etc.

During the 1st field work in Uganda, the Project Team held discussions with MoWT's focal counterparts (hereafter referred to as C/P) from the Department of Mechanical Engineering Services and the Department of Roads and Bridges, and explained the basic policy, method, and work schedule based on the drafted Work Plan for project implementation. In addition, the Project Team conducted the field

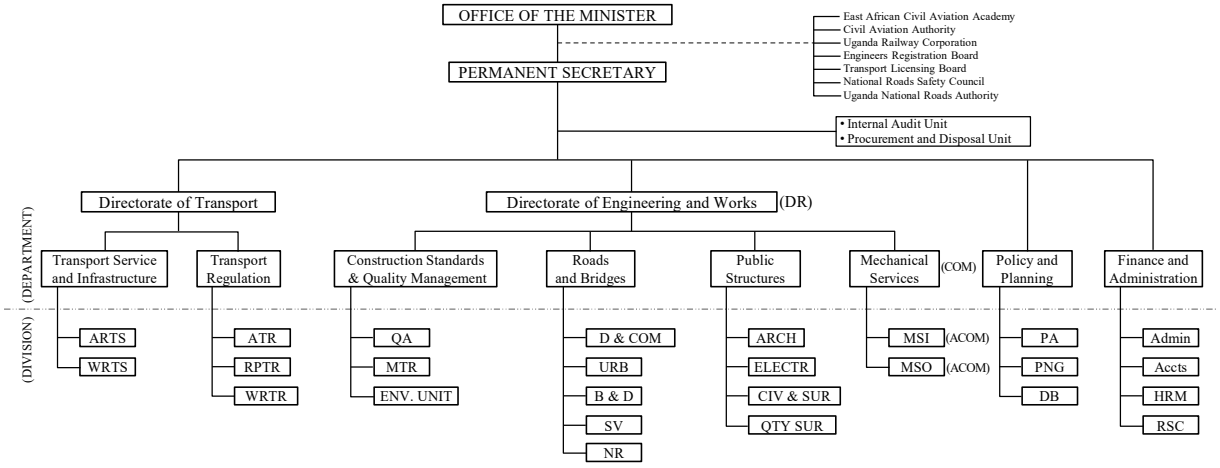
investigation to grasp the current situation and identify issues related to the capacities of C/P to maintain roads and to operate and manage road equipment. Through field investigations and discussions with the C/P, the Work Plan was finalized based on the agreement of MoWT's C/P (see Appendix-1 "Work Plan").

The list of members and organizations involved in the Project is shown in Appendix 2.

Chapter 2. Issues and Assistance Policy

2.1 Organization Structure of MoWT

The entire organization structure of MoWT is shown in Figure 2-1.



Abbreviations

Transport Service & Infrastructure	Transport Regulations	Roads and Bridges	Public Structures	Policy and Planning
ART: Air & Road Transport Service	ATR: Air & Road Transport Regulation	D & COM: District and Community Roads	ARCH: Architecture	PA: Policy Analysis
WRT: Water & Rail Transport Service	RPTR: Roads & Pipeline Transport Regulation	URB: Urban Roads	ELECTR: Electrical Engineering	PNG: Transport and Works Planning
		B & D: Bridge & Drainage	CIV & STR: Civil & Structural Engineering	DB: Data Base Section
	WRTD: Water & Rail Transport Regulation	SV: Surveying Section		
		NR: National Roads	QTY SUR: Quantity Survey	Finance & Administration
DR: Director	Construction Standards and Quality Management	Mechanical Service		Admin: Administration
COM: Commissioner		MSI: Mechanical Service Inspections		Accts: Accounts
ACOM: Assistant Commissioner	QA: Quality Assurance			HRM: Human Resource Management
	MTR: Materials Test &	MSO: Mechanical Service Operations		
	EMV.UMI: Environmental Unit			RSC: Resource Centre

Source: MoWT

Figure 2-1 MoWT Organization Structure, as of April 2021

Of the MoWT organization structure above, structures of individual departments/divisions listed below aimed at technical assistance in the Project are shown in Appendix-3.

- ➢ Department of Roads and Bridges
  - District and Community Access Roads Division
  - Urban Roads Division
- ➢ Department of Mechanical Engineering Services
  - Mechanical Service Inspection Division
  - Mechanical Service Operation Division

(1) Operational System for Road Maintenance by the Department of Roads and Bridges

Road maintenance works for rural roads and urban roads in Uganda used to be implemented by private outsourcing method. However, road projects using this method had some problems such as management problems, lack of construction quality, etc. In order to resolve that situation, in 2012 the government of Uganda changed its policy to a direct operation system called the Force Account for road construction

and maintenance except national roads. As a result, since 2012, MoWT and local governments has worked together in road maintenance of rural roads and urban roads with the basic policy, that is, minor maintenance work is carried out by local governments, and major rehabilitation and/or construction is carried out by the Force Account.

In January 2013, MoWT issued the Force Account Guidelines as a framework for planning and implementation of road maintenance. The guidelines stipulate methodologies for planning and implementation, actions to be taken by related organizations, etc., in accordance with the basic policy of the Force Account. Moreover, the Force Account Guidelines were revised in August 2017, and prior to the revised edition, the Budget Monitoring and Accountability Unit (BMAU) under the Ministry of Finance, Planning and Economic Development pointed out five issues as the Key Policy Gaps for further improvement as shown in Figure 2-2.

- Inconsistencies within the URF and URA Acts
- Low operation funds allocation to designated agencies
- Not fully operational District Roads Rehabilitation Units
- Inadequate remuneration to the gangs
- Inadequate numbers and funding of the regional mechanical workshops

Source: BMAU Briefing Paper, May 2017

Figure 2-2 Key Policy Gaps

The Guidelines stipulates the target users at the central and local government levels who should utilize it. Table 2-1 shows the classification and outline of works, construction method and structure for road maintenance and rehabilitation works stipulated by the latest Guidelines.

Table 2-1 Classification and Outline of Works, and Construction Method and Structure for Road Maintenance and Rehabilitation Works stipulated in Force Account Guidelines

Classification of Works	Outline of Works	Construction Method (Manual/Mechanized) and Structure
1. Routine manual maintenance Target: gravel road, urban tarmac road	➢ Maintain the roads in serviceable condition throughout the year. ➢ Effective when the road has engineered features (camber, cross-fall and longitudinal gradient).	➢ Manual work by gangs ➢ A man-2km principle (i.e. one man maintaining 2 km of a gravel road or four men maintaining 1km of urban tarmac road per month) ➢ For gravel roads, gangs consisting of 10 workers work under a headman and maintain a section or sections of road totaling 20 km. ➢ An overseer superintends over a maximum of 5 headmen. ➢ Implemented by a local government
2. Routine mechanized maintenance Target: gravel road, urban tarmac road	➢ Replacement of lost gravel, light grading and re-shaping with a motor grader to restore the road shape. ➢ Carry out at intervals of 3 to 4 years depending on traffic volumes/axle loads, environmental (weather) conditions and initial quality of gravel. ➢ Best when it is carried out at the end of the rainy season.	➢ Mechanized work ➢ Implemented by a local government using zonal equipment distributed to it ➢ Sealing of urban roads is executed by the Urban Road Sealing Units under MoWT

3. Periodic maintenance of district roads Target: gravel road	➢ Grading, shaping and re-gravelling ➢ For gravel roads, carry out when it has lost more than 70% of the original gravel irrespective of whether it has lasted 3 years or less. ➢ For urban roads, include sealing and re-construction to bitumen standard.	➢ Mechanized work ➢ Implemented by a local government using zonal equipment distributed to it ➢ Rehabilitation of district roads is executed by the District Road Rehabilitation Units under MoWT
4. Rehabilitation Target: district road, urban road	➢ Restoring the road to its original condition. ➢ Opening and upgrading of earth roads to gravel standard.	➢ Mechanized work ➢ Implemented by the Force Account when

Source: Revised Force Account Guidelines, August 2017

As shown in Table 2-1, although the scope of road maintenance and rehabilitation works, outline of works, method and structure, etc. are stipulated, well-planned road maintenance according to the said scope are not sufficiently implemented.

As for MoWT's budget allocation process for road maintenance and rehabilitation, firstly, the road engineer in charge of each region of the country submits an assessment report summarizing the survey results with estimated costs for candidate roads to be maintained or rehabilitated in the next fiscal year to the MoWT headquarter. Then, the headquarter screens candidates, and proceed to a budget application and approval procedures based on its final selection. When MoWT's road engineer prepares the assessment report, the engineer estimates labor costs, fuel costs, other expenses, etc. for respective works based on their own experience, and the cost amounts to be budgeted are accurately calculated by them. On the other hand, road engineers in regions grasp a demand for road maintenance or rehabilitation in the area under their jurisdiction, list up candidate roads for taking actions, and submit the assessment report to the headquarter. Only the roads less than half of the entire list are selected under chronic budget shortage of the government. As a result, the maintenance needs of rural roads are not adequately addressed.

After a new construction or rehabilitation work carried out by MoWT, a implementing organization for road maintenance is transferred to the one of local governments. Periodic inspection and small-scale road maintenance are inadequate, and a corrective maintenance that repeats large-scale rehabilitation after years has been normalized.

In the above situation the Project Team determined to study and propose an improvement method for the road management system that would be feasible under the MoWT's current implementation structure and budgetary condition.

(2) Equipment Management Structure by the Department of Mechanical Engineering Services

Road maintenance equipment under MoWT is operated and maintained by mechanical workshops located in four areas, namely Kampala, Bugembe, Gulu, and Mbarara.

Table 2-2 shows the outline of mechanical workshops under MoWT.

Table 2-2 Outline of MoWT Mechanical Workshop

Name	Outline
Kampala Central Mechanical Workshop	This Workshop is located in MoWT head office in Kampala. At present, only machining, welding, and woodworking shop are remained as production sections, and its function as a mechanical workshop is limited. The Workshop has jurisdiction over the central region of the country including Kampala.
Bugembe Regional Mechanical Workshop	This Workshop was developed in 1996 under Japanese grant aid. Although the workshop premises is a little small, it has the most complete facilities, workshop equipment and tools among MoWT's workshops. The Workshop has jurisdiction over the eastern region of the country.
Gulu Regional Mechanical Workshop	The roofed building as a mechanical workshop is only a service pit for small vehicles. Equipment maintenance is carried out outdoors, which also serves as a parking lot. There is also a shortage of workshop equipment and tools. The Workshop has jurisdiction over the northern region of the country.
Mbarara Regional Mechanical Workshop	The roofed building as a mechanical workshop is only a parts warehouse and a storage area for equipment awaiting repair. Equipment maintenance is carried out outdoors, which also serves as a parking lot. There is also a shortage of workshop equipment and tools. The Workshop has jurisdiction over the western region of the country.

Source: JICA Project Team

Since MoWT procured road maintenance equipment with loans from JBIC and a major Japanese bank in 2017, it has outsourced equipment maintenance, including periodic maintenance, to private dealers which are authorized distributors appointed by Japanese manufacturers. The outsourcing contract was planned to expire in April 2023, and with regard to implementing structure to maintain equipment after May 2023, the Project Team planned to give assistance to strengthen MoWT’s structure with the option of continuously using private dealer’s services.

2.2 Capacity Assessment regarding Technical Evaluation Items

In order to grasp the capacity and analyze issues of road engineers, equipment operators, mechanics, etc. of MoWT and related organizations, and the utilization and management of existing road equipment, the Project Team conducted a field survey and interviews in the 1st field work. The capacity of MoWT engineers, etc. was confirmed according to the evaluation items shown in Table 2-3.

Table 2-3 Technical Evaluation Items and Current Status (as of May 2021)

Evaluation Items		Confirmation Items	Results
Road Construction and Maintenance	Road Construction and Maintenance Work	1. Can he prepare or understand a construction plan (methods, materials, personnel and equipment, execution processes, quality control items, safety measures, points to be noted in construction, etc.) that meet the site condition?	The site manager of the Force Account has a certain level of technical understanding. It is necessary to give assistance and technical advice on individual issues through the Project.
		2. Can he carry out the works according to the construction plan?	Under the direction of the site manager, construction works can be carried out. However, further understanding and practices of safety measures at the site are required. It is necessary to give assistance and technical advice on individual issues through the Project.
		3. Can he provide adequate instruction and management to equipment operators and workers?	A road engineer can give his instruction when needed. However, further knowledge including more effective use of equipment, safety measures, etc. are required. In particular, road engineers need to work together with the equipment team and supervise operators properly to improve efficiency in equipment operations at sites.
		4. Can he share information on the operation status of equipment at the site, the presence or absence of defects, etc. with the Central Mechanical Workshop and the Regional Workshops in a timely manner?	It is necessary to make daily or regular communications on the equipment status with the Regional Mechanical Workshop. The Project Team attempts strengthen a communication system between the civil team and the mechanical team.
		5. Can he manage to control placement and operation of construction equipment?	It is necessary to establish a better communication system so that the civil team can quickly contact and coordinate with the Regional Mechanical Workshop in case that equipment malfunction occurs. The Project Team attempts strengthen a communication system between the civil team and the mechanical team.
	Road Inspection, etc.	1. Can he appropriately carry out daily and periodic inspections of roads under jurisdiction, emergency inspections after disasters, etc.?	The civil team carries out a road inspection occasionally. However, the frequency of inspections has not been systematized, and it is common practice to conduct a survey and inspection after the road conditions have changed significantly due to deterioration over time or rainfall disasters. In the future, it is desirable to systematize daily and periodic inspections and shift from the current corrective maintenance system to a preventive maintenance system.
		2. Can he accurately report the damage and deterioration status of roads based on the inspection results?	The template for reporting is described in the Road Maintenance Management Manual. MoWT's road engineer submits an assessment report summarizing (1) the current condition of the target road, (2) the necessary repair works and costs, and (3) the findings of the engineer based on the result of their field survey. The report is used by the MoWT headquarter for judging the necessity of road maintenance or rehabilitation work.
		3. Can he understand the necessity and urgency of repair plans according to the extent and extent of damage and deterioration?	Indicators for judging the necessity and urgency of maintenance are described in the Road Maintenance Management Manual. However, the manual is deemed not fully utilized, and the corrective maintenance against

			for damage and deterioration that require large-scale rehabilitation is commonly carried out by MoWT.
Construction Equipment Management	Inventory of Equipment	1. Whether basic data such as equipment type, registration number, basic specification (type, maker, model, manufacturing year, serial no., capacity, engine output, purchase price, etc.) are recorded and the machines' conditions are updated.	Based on a comprehensive service agreement with a private dealer, the dealer manages the basic data of equipment. Through sharing equipment status (including minor maintenance records, etc.) with private dealers over the service life of equipment, MoWT is expected to actively utilize private dealers.
		2. Whether machines' data are utilized for equipment management.	
	Operation Record	1. Whether machines' operation record (data) are updated regularly.	Operational data for equipment, to which mechanical services are provided by the private dealer, is updated by the dealers. On the other hand, there are occasional shortages and delays in updating the equipment status managed by MoWT and host organizations. In the future, as a means for MoWT itself to record and update operational data, it is conceivable to use the GPS tracking system installed on equipment.
		2. Whether machines' operation data are utilized for equipment management.	Operational data for equipment, to which mechanical services are provided by the private dealer, is utilized by the dealers. Operational data of equipment managed by MoWT and host organizations is insufficient. In the future, MoWT is expected to manage operational data by using a GPS tracking system.
	Maintenance Record	1. Whether machines' maintenance/repair data are recorded properly.	Maintenance and repair data for equipment, to which mechanical services are provided by the private dealer, is updated by the dealers. Maintenance and repair data for equipment managed by MoWT and host organizations is recorded in hard copy (paper), but it is not stored as data. MoWT needs to keep in touch with dealers to keep track of the equipment status in a timely manner.
		2. Whether machines' maintenance/repair data are utilized for equipment management.	Maintenance and repair data for equipment, to which mechanical services are provided by the private dealer, is utilized by the dealers. The management of maintenance and repair data for equipment managed by MoWT and host organizations is insufficient. MoWT needs to keep in touch with dealers to keep track of the equipment status in a timely manner. In addition, it is desirable to share maintenance records with dealers for minor maintenance carried out by MoWT itself.
	Spare parts inventory control	1. Whether receipts and issues of spare parts are recorded properly.	Spare parts are procured on an as-needed basis, and regional mechanical workshops keep a limited stock of parts. On the premise of continuing the above system, MoWT needs to systematically procure additional parts according to the parts inventory and operational status of equipment.
		2. Whether there is proper awareness of spare parts consumption (frequency of use) and quantities in inventory.	
		3. Whether spare parts data are utilized for equipment management.	
Instructor for Operator	Inspection	1. Can he teach (coach) pre-operation inspection and closing inspection?	TOT for improving operator's capacity is carried out by the UNIDO project. The Project collaborates with the UNIDO project. The UNIDO project aims a following goal in its operator training program. ➢ MoWT master trainer: 50 persons

			➢ Operator: 360 persons ➢ Youth in human development: 80 persons In addition, the UNIDO project develops a Operator Training Center in Luweero district.
	Operation	1. Can he read (understand) indications of meters and gauges properly?	There is room for further capacity improvement in skill. TOT for improving operator's capacity is carried out by the UNIDO project. The Project collaborates with the UNIDO project, grasps progress in UNIDO's training and give a recommendation when needed.
		2. Can he work skillfully by using equipment?	
		3. Can he teach (coach) how to operate equipment and how to work by using equipment?	
	Safety Work	1. Does he fully understand safety work in the construction site?	According to the MoWT Road Maintenance Management Manual, it explains as follows for example: ➢ "It is the responsibility of the maintenance foreman or supervisor to insist that all risks are minimized." ➢ "Operators and laborers alike must be informed of the potential risks and of procedures for working or close to machinery." On the other hand, safety work currently depends on the knowledge and experience of individual supervisors at each site, and operators are not fully aware of the precautions to be taken when operating equipment or when parking it. Since TOT by the UNIDO project includes safety instructions, the Project collaborates with the UNIDO project and give a recommendation when needed.
		2. Can he teach (coach) how to operate equipment safely and how to work safely?	Knowledge of hazard prediction and preventive measures depends on the site supervisor's experience. Therefore, it is desirable to standardize the knowledge and experience of supervisors on safe work as much as possible.
Instructor for Mechanic	Tools and Equipment	1. Can he manage to use (operate) mobile workshop?	The utilization of the mobile workshop is limited. It is necessary for MoWT to understand the specifications and performance of mobile workshops and to improve their capacity for maintenance of equipment, including safety work. A mobile workshop will be used as one of the teaching materials in the TOT for training equipment mechanics implemented in this project.
		2. Can he use tools and workshop equipment skillfully?	There is room for further capacity improvement in knowledge and skill. MoWT's regional mechanical workshops have a shortage of workshop equipment and tools, and the arrangement of them in the workshops is also inadequate. It is necessary to encourage an understanding of the necessity and handling of workshop equipment and tools.
	Safety Work	1. Does he fully understand safety work in the workshop?	There is room for further capacity improvement in knowledge and skill. In particular, it is desirable to improve knowledge and skills regarding slinging for crane works. General safety education including sling work should be provided through the TOT in the Project.
		2. Can he teach (coach) safety work in the workshop?	There is room for further capacity improvement in knowledge and skill. It is necessary to provide training on safety

			guidance for mechanics through the TOT in the Project.
	Repair Work	1. Does he fully understand structure and function of the components/devices equipped for the construction equipment?	There is room for further capacity improvement in knowledge and skill. It is necessary to acquire knowledge about the structure and function of equipment by utilizing actual equipment through the TOT in the Project.
		2. Does he have skill to inspect and maintain/repair construction equipment?	There is room for further capacity improvement in knowledge and skill. It is necessary to implement the OJT for periodic inspection and maintenance work of equipment by using actual equipment through the TOT of the Project.
		3. Can he teach how to inspect and maintain/repair construction equipment (theory & practice)?	There is room for further capacity improvement in knowledge and skill. It is necessary to train instructors for inspection and maintenance work by using actual equipment through the TOT of the Project.
Manager for Equipment Management	Workshop Management	1. Can he manage workshop and spare parts store operation?	MoWT procures necessary spare parts from private dealers as it needs. In continuing utilizing private dealers, MoWT needs to procure additional parts according to the parts inventory and operational status of equipment.
	Equipment Management	1. Can he manage to control repair/maintenance of construction equipment?	The managers of MoWT's regional mechanical workshops have a certain level of ability to manage equipment, although there are some individual differences. However, it is desirable to further improve their capacity in order to operate and maintain their equipment more efficiently. It is necessary to improve equipment management capacity in cooperation with private dealers.
		2. Can he carry out troubleshooting of construction equipment and give proper directions to mechanics?	
		3. Does he understand procurement procedure of spare parts and availability of suppliers?	
	Budget Management	1. Does he understand budget management (spare parts procurement and maintenance/repair of construction equipment)?	Shortage of the equipment maintenance budget has been normalized. It is necessary to give advice on the necessary budget scale for appropriate maintenance of equipment through the Project.

Source: JICA Project Team

Based on the results described above, the Project Team proposed to provide the following technical assistance comprised of a) and b) through the Project.

a) Technical assistance for improvement of road maintenance system and efficiency

- To assist to maintain roads under its jurisdiction as assets as a road administrative agency, and to utilize the knowledge and lessons learned through the maintenance cycle of roads for future planning, design, construction supervision, etc.
- To assist to promote road maintenance by effectively using road maintenance equipment through horizontal collaboration between the civil team and the mechanical.
- To propose for improvement of policy making, planning, and budgeting.

b) Technical assistance for improvement of the capacity of equipment operation and maintenance

- To strengthen the implementation structure in collaboration with private dealers for efficient operation and maintenance of equipment.
- To implement the TOT program for training mechanics, and assist for future self-development.
- To advise on budget issues, etc. for proper operation and maintenance of equipment.

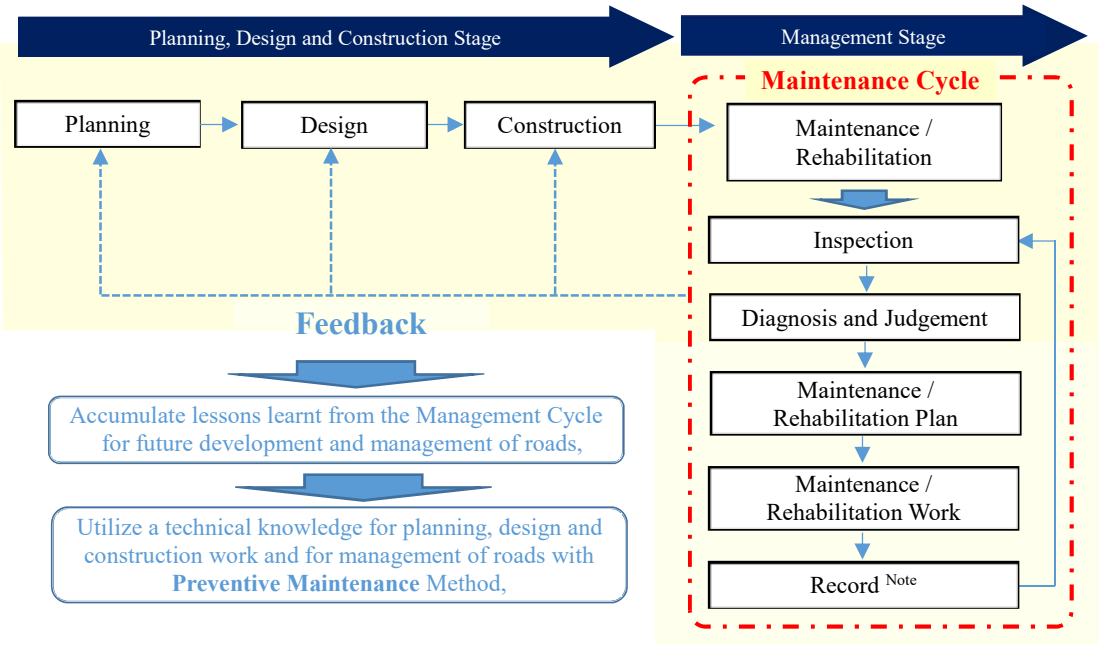
Chapter 3. Activity Report

3.1 Technical Assistance for Improvement of Policy Making, Planning and Budgeting in Road Management

(1) Introduction of Asset Management

First, the Project Team explained the importance of a cycle of Asset Management, including survey/planning, design, construction, maintenance/renewal, in order for MoWT to improve a system of maintenance and rehabilitation works of roads under its jurisdiction, and to manage roads over the long term.

Moreover, the Project Team encouraged an understanding of road management based on an asset management flow. Figure 3-1 shows a work flow of the Asset Management to contribute to proper road management system.



Note: Database system for district and urban roads is effectively utilized in records of maintenance and rehabilitation work.
Source: JICA Project Team

Figure 3-1 Work Flow in Asset Management

In implementing the maintenance cycle at the management stage shown in Figure 3-1, the Project Team advised active utilization of the database system for district and urban roads developed in the JICA's past project.

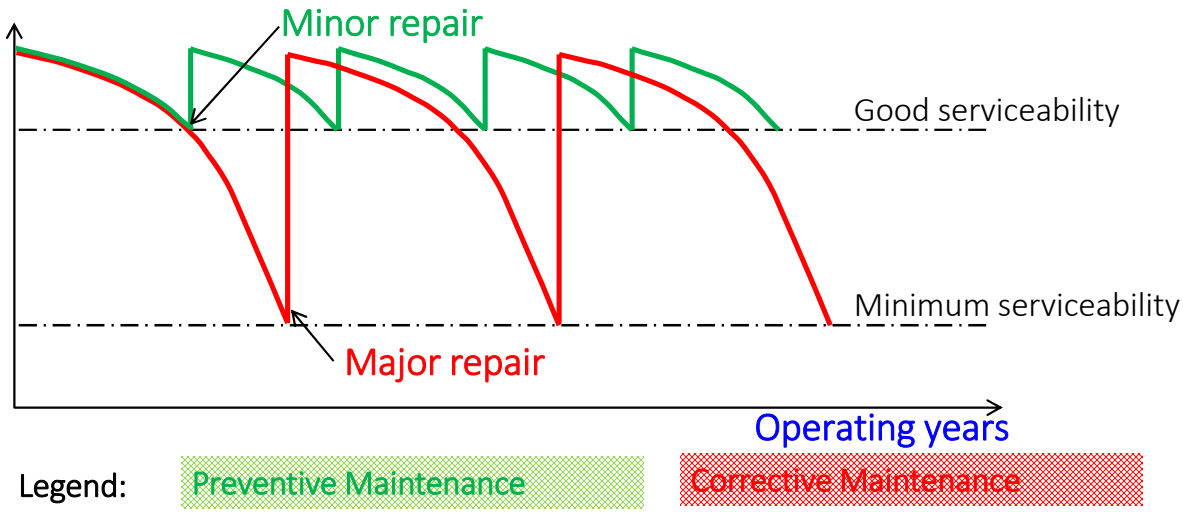
(2) Preventive Maintenance System

MoWT has been performing post-maintenance called as a Corrective Maintenance System, and have been forced to carry out costly large-scale road rehabilitation works. After all, rehabilitation costs tend to increase as a result of being left uncontrolled for many years without being able to respond within a

limited road maintenance budget. In order to improve current situation, the Project Team explained the necessity of shift MoWT's maintenance method to a Preventive Maintenance System.

Moreover, the Project Team explained an example of small-scale maintenance in the Preventive Maintenance System, and the Team compared maintenance costs between preventive and corrective maintenance for the selected case example of road section under the jurisdiction of MoWT, and encouraged an understanding of superiority of the Preventive Maintenance System.

Figure 3-2 shows a conceptual diagram comparing the Corrective Maintenance and the Preventive Maintenance in the life cycle of road.



Source: JICA Project Team

Figure 3-2 Comparison of Maintenance Systems

Examples of small-scale maintenance with suitable equipment for works in case of the preventive maintenance and cost comparison with the corrective maintenance are summarized in Appendix 6 "Recommendations" and the Project Team explained in the 5th field work.

(3) Proposed Maintenance Frequency and Timing according to Road Classification and Service Level

In encouraging the preventive maintenance mentioned in the above previous section, it was important to set the frequency and timing of road maintenance in consideration of MoWT's annual budget constraints. For rural roads, there seems to be no clear criteria for judging the priority of maintenance or rehabilitation. The Project Team proposed to set a quantitative indicator to determine road surface conditions that require maintenance through discussions with the C/P.

Moreover, when prioritizing road maintenance, it is realistic to comprehensively judge not only the road condition but also the evaluation items such as the characteristics of roads to be considered and social circumstances, etc. Therefore, the Project Team proposed to introduce a point-adding method with evaluation items to determine the priority of maintenance.

The proposal for the above-mentioned quantitative indicator of road conditions and the point-adding method are summarized in Appendix 6 “Recommendations” and the Project Team explained in the 5th field work.

3.2 Technical Assistance for Improvement of Road Maintenance System and Efficiency

(1) Proper Use of Road Maintenance Equipment in Collaboration with Mechanical Team

Through the Project implementation, officials of the Department of Roads and Bridges (i.e. civil team) and the Department of Mechanical Engineering Services (i.e. mechanical team) hold a joint workshop (hereafter referred to as the joint workshop) to share the current status of road maintenance and equipment maintenance and exchange opinions on issues for improvement. In the joint workshop, the mechanical team explained the outline of the GPS tracking system, and the data that can be collected from the system, such as the location of equipment, working days and hours, and the travel time of equipment (e.g. excavator), fuel consumption, etc. shared to all participants.

Based on the data collected from the GPS tracking system, the participants of the joint workshop grasped actual conditions and issues regarding the use of equipment in road maintenance and rehabilitation works by the civil team. Then, the participants exchanged opinions to resolve the grasped issues, and finally the resolution plan for future improvement was formulated as the Action Plan as shown in Table 3-1.

Table 3-1 Challenges, Resolutions and Responsible Entity/Persons in Road Maintenance Using Equipment

S/N	CHALLENGES	RESOLUTIONS	RESPONSIBLE ENTITY /PERSONS
1	Wear of undercarriage	➢ Long Equipment travel should be avoided ➢ Plan for the shifting of the equipment	➢ Plant operator ➢ Civil engineer and mechanical foremen
2	Use of equipment when it is overdue for service	➢ Equipment should be parked whenever it is due for service. ➢ Service should only be under taken by trained persons.	➢ Regional mechanical workshops ➢ Plant operators ➢ Mechanical foremen
3	Political pressure	➢ All political request should be official.	➢ Permanent secretary ➢ Engineer in chief ➢ Regional managers
4	Lack of KOMTRAX information	➢ All managers and mechanical foremen should liase with TOT-mechanics and registered personnels	➢ TOT-Mechanics
5	Over consumption of fuel	➢ Follow up on fuel consumption by use of komtrax ➢ Operators should be encouraged to use Eco mode when in normal operating situation	➢ TOT mechanics and registered personnel.

Source: Prepared by the participants of the joint workshop

The participants of the joint workshop horizontally develops the resolution plan shown in Table 3-1

within the organization, and the mechanical team and the civil team will regularly monitor the practice through the data to be collected by the GPS tracking system, accordingly.

In the future, in order for MoWT to utilize its equipment appropriately and promote road maintenance, close communication and reporting between the civil team and the mechanical team are essential. Therefore, through the joint workshop between both teams, the Project Team encouraged the understanding of importance of close collaboration as well as utilization of the GPS tracking system.

Before the Project, no one of MoWT used the GPS tracking system. Now the mechanical team could share the outline of the system, utilization methods, etc. with the civil team. After sharing so, the Department of Roads and Bridges (i.e. civil team) prepared a list of responsible managers (e.g. Force Account Managers, Deputy Force Account Managers) to be involved in the operation of the GPS tracking system and submitted it to the Department of Mechanical Engineering Services (i.e. mechanical team). Based on this list, the managers will also register access rights to the system as necessary so that and both teams will be able to jointly monitor status of their challenge.

(2) Effective Use of Database System for District and Urban Roads

Through a technical discussion with engineers in charge of the district and urban road database handled by the Department of Roads and Bridges, the Project Team recognized some issues regarding procedures for inspection and monitoring work after the completion of road maintenance works and budget shortages. Table 3-4 describes the operational status and issues to be improved.

Table 3-4 Operational Status and Issues to be improved on the Database.

Operational status	Issues to be improved
After completion of road maintenance works, MoWT engineers will travel to respective regions for final inspection, and personnel expenses, travel expenses and allowances, vehicle fuel costs, etc. will be required each time. Moreover, in the inspection, it is a rule that some technical staff from local governments (2 staff for rural roads and 4 staff for urban roads) participate, and the cost of these staff from local governments also needs to be borne by MoWT.	To reduce a cost for road inspection
Although the final inspection is devised to be carried out collectively for each area as much as possible, it takes about 3 days for the inspection and information collection per district, and about 7 days for the subsequent GIS map editing work. The length of roads that can be inspected per day for each road type is 15 km per day for Urban Roads, 35 km per day for District Roads, and 20 km per day for Community Access Roads. In particular, because it is relatively difficult to carry out inspections by vehicles on the Community Access Road, inspectors have no choice but to carry out field surveys on foot, resulting in poor work efficiency.	To improve efficiency in road inspection

Source: Prepared by JICA Project Team based on interviews with MoWT engineers

As of July 2022, there are a total of 136 districts in Uganda. The database management team of MoWT updates the database according to the performance of road maintenance work in each district each year, with their target to cover all 136 districts in every 2 years, which means that 68 districts are targeted every year. However, the results are insufficient to meet the target. As an example, Table 3-5 shows the

outcome in database update in financial year 2021/22.

Table 3-5 Outcome in Road Database Update (Financial Year 2021/22)

Unite: Number of District

Indicator	Goal	Outcome	Achievement Ratio
Number of district updated in the year	68	27	40%
Number of district updated every quarter	17[Note 1]	1st : 0 [Note 2] 2nd : 9 3rd : 9 4th : 9	0% 53% 53% 53%

Note 1: According to the current efficiency of inspection, 1 inspector of MoWT can perform an average of 3 districts every quarter. Therefore, in order to achieve the goal, it is necessary to deploy about 6 engineers.
Note 2: In the first quarter of the year, a work progress is subject to a schedule of budget allocation.
Source: Prepared by JICA Project Team based on interviews with MoWT engineers

Based on the above situation, in order to improve database management within a limited budget, it is important to improve the efficiency of road inspection and to reduce costs. Simplifying and speeding up inspections according to road classification are considered as possible measures, and introducing a drone for site inspections of the Community Access Road is one of technically feasible approach as proposed and discussed with engineers.

(3) Measures for Cost Reduction on Road Construction and Maintenance

After the Project Team confirmed the pavement structure and construction method, which was implemented by MoWT, through site investigations, the Team introduced a case example that contributes to the cost reduction of road construction by applying a pavement structure optimized according to future traffic forecasts, etc. The said case example was summarized in Appendix 6 “Recommendations” and the Project Team explained in the 5th field work..

3.3 Technical Assistance for Improvement of the Capacity of Equipment Operation and Maintenance

(1) Effective Use of Private Sector Services

The Project Team explained the rationality of using private sector services in the future in terms of the facilities and implementation structure of mechanical services by the existing Regional Mechanical Workshops under the Department of Mechanical Engineering Services, and proposed the scope of services that should be shared with the private sector.

Areas of mechanical services to be undertaken by MoWT’s direct operation and areas to receive private sector services are defined as shown in Table 3-6, which was determined through the Project.

Table 3-6 Scope of Mechanical Services to be undertaken by MoWT and Private Sector

Service level	Type of equipment servicing and repair	Main work items	Demarcation		
			MoWT		Manufacturer / Local Dealer
			Central Workshop	Regional Workshops	
1 Light	Periodical Maintenance	Change lubricants, lubrication	○	○	
2	Inspection and adjustment	Adjusting brake, adjusting clutch etc.	○	○	
3	Minor repair and maintenance	Replacement of consumable parts	○	○	
4	Overhaul of the main component	Engine, clutch, transmission, hydraulic component etc. (mechanical component/device)	△ Note 1	△ Note 1	○
		Undercarriage of construction equipment (part replacement) Note 2	○	○	○
5 Heavy	Trouble shooting and repair of electronic component /device	Electric/electronic/hydraulic control system, for engine, power train and hydraulic component etc.			○
6	Major overhaul and repair, and modifications	Major overhaul/repair of equipment and modifications			○

Note 1: JICA expert understands that MoWT has experience and achievements for small vehicles. Therefore, a repairing work of small vehicles are classified as MoWT's direct operation..

Note 2: Replacement of parts around the undercarriage of construction equipment is going to be carried out by MoWT directly or by utilizing private service providers, depending on the content of maintenance and MoWT's budgetary conditions.

Source: Prepared by MoWT and JICA Project Team

(2) Training of Trainers (TOT) Programme for Development of Mechanics

For assistance for improving capacity to achieve the scope of mechanical services defined as Table 3-6, the Project Team conducted the TOT programme targeting MoWT's mechanics. Table 3-7 shows the outline of the TOT programme.

Table 3-7 TOT Programme

Training Course	Implementation period / Instructor	Training Items	Result
1. Basic Course (Common) for Vehicle	2nd field works / NVTC Note 1 and JICA expert	Subject: Electrical equipment related to the vehicle ➢ The basics of electricity ➢ The basics of electronics. ➢ How to use the circuit tester ➢ How to use the failure diagnosis equipment ➢ Pneumatics and the basics of all pneumatics control circuits ➢ Pneumatics and hydraulic machine maintenance	Completed in 2nd field work
2. Basic Course (Common) for Construction Equipment	3rd to 5th field works / JICA expert	Subject: Construction equipment ➢ Outline ➢ How to use and teach measuring equipment ➢ Engine ➢ Electrical equipment ➢ Hydraulic system ➢ How to use welding equipment ➢ Undercarriage (wear resistant) ➢ How to do safety slings work ➢ Preparation of technical report for equipment repairing	Completed in 5th field work
3. Advanced Course for Heavy Equipment (KOMATSU)	3rd field works / Local dealer and JICA expert	Subject: Monitor operation and diagnosis method ➢ How to operate the monitor panel of the following equipment ➢ How to do diagnosis using the monitor panel ➢ GPS tracking system utilization method ➢ General maintenance works, etc.	Completed in 3rd field work
4. Advanced Course for Vehicle (FUSO)	4th field works / Local dealer and JICA expert	Subject: Proper maintenance operation** for compaction equipment; How to maintain, diagnose and repair the following items. ➢ Engine system ➢ Transmission system ➢ Clutch system ➢ Brake system	Completed in 4th field work
5. Advanced Course for Compaction Equipment (SAKAI)	5th field works / Local dealer and JICA expert	Subject: Proper maintenance operation** for compaction equipment; How to maintain, diagnose and repair the following items. ➢ Engine system ➢ Transmission system ➢ Hydraulic system ➢ Brake system ➢ Undercarriage	Completed in 3rd field work
6. Practical Training Course with OJT	3rd to 5th field works / JICA expert	Subject: OJT on the following items. ➢ Measuring equipment ➢ Engine ➢ Electrical equipment ➢ Hydraulic system ➢ How to use welding equipment ➢ How to do safety slings work ➢ Preparation of technical report for equipment repairing	Completed in 5th field work

Note 1: NVTC stands for Nakawa Vocational Training College
Source: JICA Project Team

8 members, which was organized by 2 members nominated from Kampala Central Workshop and 2 each from 3 Regional Workshops (i.e. Bugembe, Gulu and Mbarara) respectively, continuously participated in the TOT until its completion. Attempting that these 8 members will serve as instructors for training mechanics in the future, MoWT nominated them in terms of not only their technical experience and skills, but also communication ability.

In Table 3-7, for Advanced Courses targeting heavy equipment, vehicle and compaction equipment, the

Project Team proposed to receive supplemental support for the TOT from local private dealers (authorized agents) through discussions with MoWT, and conducted these Advanced Courses. The 3 private dealers that cooperated with Advanced Course and the Nakawa Vocational Training Collage (NVTC) that cooperated with the Basic Course for vehicle offered training costs to cooperate with respective courses, MoWT, however, covered all the costs at its own budget so that the Project could was able to conduct sufficient trainings in all training courses.

After completing the entire course of the TOT programme, a written test and a practical test were conducted for the 8 TOT members. After receiving the test results, a certificate of training completion was awarded to all TOT members in reply to MoWT's demand.

Finally, the Project Team compiled a curriculum and training materials for training mechanics so that MoWT will be able to develop maintenance training by itself even after the Project.

(3) Annual Maintenance Costs estimated for Service Life Time of Equipment

MoWT procured 1,152 units of various equipment in 2017 through JBIC loan scheme. The Project Team calculated an annual maintenance cost as per maintenance items for those equipment expected over the service life and explained it. It has passed 5 years as of 2023 since MoWT procured, it is important to ensure the annual maintenance budget because equipment will require more and more maintenance.

Table 3-8 shows the expected regular and irregular maintenance items over the service life of equipment.

Table 3-8 Items of Equipment Maintenance

Classification	Service time	Maintenance items
Regular	250-500 hours	Engine oil, hydraulic oil, engine oil filter, fuel filter, grease (as needed)
	2,000～2,500 hours	Reversal (reuse) of pins and bushings of equipment (bulldozers, hydraulic excavators) that travels with a crawler system
	3,500～4,000 hours	Replacement of undercarriage parts for equipment (bulldozers, hydraulic excavators) that run on crawler system
	per constant consumption	Vehicle tire replacement, construction machinery tooth and edge replacement
Irregular	―	Maintenance and repair of engines (overhaul), transmissions, hydraulic pumps, motors, hydraulic cylinders, brakes, cooling systems, air conditioners, body sheet metal, glass, etc.

Source: JICA Project Team

Moreover, Table 3-9 shows the annual maintenance costs for equipment procured in 2017 with JIBC loan. MoWT is recommended to coordinate in the government for the allocation of annual budget in reference to the annual maintenance costs shown in the table.

Table 3-9 Annual Equipment Maintenance Costs

	Name of Equipment	Machine's life span (years)	Mainte. cost Rate (in life span) (%)	Total mainitenace cost (JPY/unit)	Av. mainte. cost/year (JPY/unit)	Mainte. cost for remained years (JPY/unit)	Mainte. cost per year for remained years (JPY per year/unit)	Number of equipment (unit)	Total mainte. cost per year for remained years (JPY)
1	Morter Grader GD663-2	10	55	10,450,000	1,045,000	6,270,000	1,254,000	143	179,322,000
2	Wheel Loader WA250-5	10	40	7,200,000	720,000	4,320,000	864,000	122	105,408,000
3	Wheel Loader WA430-5	10	30	9,600,000	960,000	5,760,000	1,152,000	13	14,976,000
4	Excavator PC220-8 Standard	10	55	13,750,000	1,375,000	8,250,000	1,650,000	21	34,650,000
5	Excavator PC220-8 Long-Boom	10	55	14,850,000	1,485,000	8,910,000	1,782,000	0	0
6	Bulldozer D65EX-16	10	55	15,400,000	1,540,000	9,240,000	1,848,000	25	46,200,000
7	Wheel Backhoe Loader	10	50	6,700,000	670,000	4,020,000	804,000	31	24,924,000
8	Vibratory Roller 10ton SV520D	10	40	3,360,000	336,000	2,016,000	403,200	141	56,851,200
9	Pneumatic Tyre rollor TS200	10	45	2,574,000	257,400	1,544,400	308,880	4	1,235,520
10	Pedestrain Roller 0.8ton HV80	10	40	752,000	75,200	451,200	90,240	18	1,624,320
11	Plate compactors 4.3Hp PC63	7	40	100,000	14,286	60,000	30,000	20	600,000
12	Tampers/Rammers RS55E	7	30	96,300	13,757	57,780	28,890	18	520,020
13	Dump Truck 8ton	10	30	3,600,000	360,000	2,160,000	432,000	276	119,232,000
14	Dump Trucks with chip spreader	10	30	4,050,000	405,000	2,430,000	486,000	7	3,402,000
15	Cargo Truck 8ton	10	45	4,686,746	468,675	2,812,048	562,410	9	5,061,686
16	Water bowser 8,000L	10	45	4,934,798	493,480	2,960,879	592,176	138	81,720,249
17	Low bed tructor pay load 30ton	10	35	12,600,000	1,260,000	7,560,000	1,512,000	9	13,608,000
18	Self-loading truck pay load 15ton	10	45	11,250,000	1,125,000	6,750,000	1,350,000	21	28,350,000
19	Mobile Workshop	10	50	9,000,000	900,000	5,400,000	1,080,000	5	5,400,000
20	Mobile crane 35ton	10	25	10,750,000	1,075,000	6,450,000	1,290,000	1	1,290,000
21	Bitumen Distributor	10	30	5,980,914	598,091	3,588,548	717,710	4	2,870,839
22	Bulldozer D85EX-15R	10	40	12,800,000	1,280,000	7,680,000	1,536,000	0	0
23	Tandem roller CR271 1.44ton	7	30	660,000	94,286	396,000	198,000	4	792,000
24	Vibratory Roller 15ton SV700	7	35	7,007,000	1,001,000	4,204,200	2,102,100	0	0
25	Vibratory Roller 18ton SV700	7	45	9,900,000	1,414,286	5,940,000	2,970,000	0	0
26	Double drum Vibratory Tandem Roller	7	50	6,545,000	935,000	3,927,000	1,963,500	1	1,963,500
27	Tandem roller SW800 10.4ton	7	25	3,325,000	475,000	1,995,000	997,500	0	0
28	Vibrator combinmed roller TW504	7	30	1,650,000	235,714	990,000	495,000	1	495,000
Total in JPY							**28,499,605**		**730,496,334**
Total in USD							**219,228**		**5,619,203**

Reference exchange rate: USD1 = JPY130
Source: JICA Project Team

(4) Countermeasure for Urgent Issue on Equipment Maintenance

Of the maintenance items shown in Table 3-8 in the previous section, the undercarriage on crawler system requires a particularly large-scale amount of maintenance costs. As of January 2023, bulldozers and excavators that run on the crawler system have exceeded 3,000 hours of operation, exceeding the permissible range for the undercarriage parts.

In order to ensure the function of the crawler system, maintenance of the undercarriage is urgently required. Specifically, it is necessary to replace old parts of the undercarriage with new parts, or otherwise to reuse the undercarriage parts by taking measures with the specific undercarriage rebuilding equipment. Otherwise, equipment with the crawler system will be inoperable due to excessive wear of the undercarriage parts.

The Project Team conducted a cost comparison to deal with the two cases of (1) replacing undercarriage parts and (2) reusing undercarriage parts rebuilt with the undercarriage rebuilding equipment, and then explained to MoWT as an urgent issue to be addressed. Details are described in Appendix 6 “Recommendations”.

(5) Advice on Future Upgrading of MoWT’s Mechanical Workshop

Of the four Central and Regional Mechanical Workshops (i.e. Kampala, Bugembe, Gulu, and Mbarara)

under MoWT, except for the Bugembe Regional Mechanical Workshop which was developed in 1996 with Japanese grant aid, other three workshop have insufficient facilities and equipment.

Based on the premise of the scope of mechanical services by MoWT shown in Table 3-6, the Project Team assumes that the existing workshop facilities and equipment will eventually need to be upgraded. In this case, considering the scale of MoWT's annual budget, it is recommended to avoid excessive workshop facility and equipment and upgrade to a simple mechanical workshop, which can be realized with the lowest initial cost. As one measure for simple mechanical workshop, the Project Team introduced a container workshop comprised of containers surrounding workshop facilities, and compiled workshop components with its initial cost for development in Appendix 6 "Recommendations".

Chapter 4. Recommendations, etc.

4.1 Recommendations to MoWT

Based on the knowledge and lessons learned from all activities in the Project, the Project Team created a recommendation document as Appendix 6 as items that MoWT is expected to work in future road maintenance and equipment operation and maintenance, and explained it to MoWT.

4.2 Remained Issues and Lessons

Future issues and lessons learned by the Project Team through the Project are shown as (1) and (2) below. These issues and lessons should be taken into consideration when MoWT implements future road maintenance and equipment operation/maintenance by itself, and similar projects will be considers in the future.

(1) Achievement and Future Issues based on Technical Evaluation Items of the Project

Table 4-1 shows the achievement status and issues at the time of Project completion based on the evaluation items described in Table 2-3.

Table 4-1 Achievement and Future Issues based on Technical Evaluation Items of the Project (as of May 2023)

Evaluation Items		Confirmation Items	Confirmation Results at Project Commencement Period (as of May 2021)	Achievement and Future Issues at Project Completion Period (as of May 2023)
Road Construction and Maintenance	Road Construction and Maintenance Work	1. Can he prepare or understand a construction plan (methods, materials, personnel and equipment, execution processes, quality control items, safety measures, points to be noted in construction, etc.) that meet the site condition?	The site manager of the Force Account has a certain level of technical understanding. It is necessary to give assistance and technical advice on individual issues through the Project.	Regarding technical issues on a construction execution plan for MoWT, the Project Team explained design methods for pavement and road drainage, points to note in construction planning (including mobilization of equipment), etc. with Japan's experiences and examples. The Team explained examples of comparing construction costs depending on differences in construction methods, and also worked to raise awareness of cost reduction. In addition, when visiting road rehabilitation sites, the Project Team grasp individual issues at each site and provided technical materials and advice for countermeasures. Through these activities, the Project Team believe that the Team were able to share Japan's experience and knowledge in optimizing the efficiency of road maintenance within the scale of the annual budget. On the other hand, due to severe budgetary constraints for road maintenance and rehabilitation of MoWT, the annual amount of maintenance work was limited, and
		2. Can he carry out the works according to the construction plan?	Under the direction of the site manager, construction works can be carried out. However, further understanding and practices of safety measures at the site are required. It is necessary to give assistance and technical advice on individual issues through the Project.	

				therefore the number of maintenance/rehabilitation sections that could be used as a good case example for technical training during the Project period was also limited. In the future, based on the annual plan for road maintenance and rehabilitation to be implemented, continuing actual practices and studies by MoWT that utilizes actual construction execution plans and/or practical opportunities in actual works will be an issue.
		3. Can he provide adequate instruction and management to equipment operators and workers?	A road engineer can give his instruction when needed. However, further knowledge including more effective use of equipment, safety measures, etc. are required. In particular, road engineers need to work together with the equipment team and supervise operators properly to improve efficiency in equipment operations at sites.	As mentioned above, since the annual work volume in road maintenance and rehabilitation of the entire MoWT is limited due to budgetary constraints, road engineers' improvement of their supervision and management capabilities is affected by how much they can have a practical experience. In the Project, the civil team (road engineers, site foreman, etc.) and the mechanical team shared information from the GPS tracking system of the equipment, both teams strengthened close communication to improve inappropriate use of equipment so that MoWT will be able to eventually improve efficiency of road maintenance and rehabilitation. In the future, the challenge is to establish a solidarity between the two teams through a series of practical opportunities, from road maintenance and rehabilitation through its planning to implementation, while continuing to monitor the data recorded by the GPS tracking system.
		4. Can he share information on the operation status of equipment at the site, the presence or absence of defects, etc. with the Central Mechanical Workshop and the Regional Workshops in a timely manner?	It is necessary to make daily or regular communications on the equipment status with the Regional Mechanical Workshop. The Project Team attempts strengthen a communication system between the civil team and the mechanical team.	
		5. Can he manage to control placement and operation of construction equipment?	It is necessary to establish a better communication system so that the civil team can quickly contact and coordinate with the Regional Mechanical Workshop in case that equipment malfunction occurs. The Project Team attempts strengthen a communication system between the civil team and the mechanical team.	
	Road Inspection, etc.	1. Can he appropriately carry out daily and periodic inspections of roads under jurisdiction, emergency inspections after disasters, etc.?	The civil team carries out a road inspection occasionally. However, the frequency of inspections has not been systematized, and it is common practice to conduct a survey and inspection after the road conditions have changed significantly due to deterioration over time or rainfall disasters. In the future, it is desirable to systematize daily and periodic inspections and shift from the	Through the Project, the Project Team explained the importance that MoWT regards roads under its jurisdiction as assets, and the importance of applying the lessons learned from the road maintenance cycle to subsequent road development and maintenance projects. Moreover, in the road maintenance and rehabilitation cycle, the Project Team encouraged the understanding of MoWT that a shift to the

			current corrective maintenance system to a preventive maintenance system.	Preventive Maintenance System that focuses on small-scale maintenance based on daily and periodic inspections would contribute to the reduction of life cycle costs. At that time, the Project Team compared the costs of the preventive maintenance and the conventional corrective maintenance, targeting specific road section under the jurisdiction of MoWT. As a result of the above mentioned activities, at the completion of the Project, MoWT's officials at management level commented that they understood the effectiveness of preventive maintenance. In the future, it is an issue that MoWT will implement daily and periodic inspections and emergency inspections after a disaster in a timely manner, objectively evaluate the priority of maintenance work based on the inspection results, and reflect it in annual work plans and budgetary arrangement. In addition, in planning an annual work in road maintenance, referring to the accumulated data in the road database system developed in the past JICA technical cooperation project, primary selection of candidate road for inspection or maintenance will help MoWT improve the efficiency of maintenance planning. The current assessment report prepared and submitted by road engineer is in a format that contains a certain amount of information necessary to understand the condition of the target road, so it can be used as a good material for judging the priority of maintenance.
		2. Can he accurately report the damage and deterioration status of roads based on the inspection results?	The template for reporting is described in the Road Maintenance Management Manual. MoWT's road engineer submits an assessment report summarizing (1) the current condition of the target road, (2) the necessary repair works and costs, and (3) the findings of the engineer based on the result of their field survey. The report is used by the MoWT headquarter for judging the necessity of road maintenance or rehabilitation work.	
		3. Can he understand the necessity and urgency of repair plans according to the extent and extent of damage and deterioration?	Indicators for judging the necessity and urgency of maintenance are described in the Road Maintenance Management Manual. However, the manual is deemed not fully utilized, and the corrective maintenance against for damage and deterioration that require large-scale rehabilitation is commonly carried out by MoWT.	
Construction Equipment Management	Inventory of Equipment	1. Whether basic data such as equipment type, registration number, basic specification (type, maker, model, manufacturing year, serial no., capacity, engine output, purchase price, etc.) are recorded and the machines' conditions are updated.	Based on a comprehensive service agreement with a private dealer, the dealer manages the basic data of equipment. Through sharing equipment status (including minor maintenance records, etc.) with private dealers over the service life of equipment, MoWT is expected to actively utilize private dealers.	Through the Project, the Project Team explained rationality of continuing to use private sector services provided by local dealers for operation and maintenance of equipment, and obtained MoWT's understanding. In the past, dealers used the GPS tracking system to monitor the status of MoWT equipment and manage the maintenance period, etc. Through the Project, MoWT became using the GPS tracking system so that it can manage equipment internally and in collaboration with private dealer. After the above activities, it is expected that efficiency of equipment management by the MoWT mechanical team will be improved, and the appropriate use of equipment by the civil team will be
		2. Whether machines' data are utilized for equipment management.		

	Operation Record	1. Whether machines' operation record (data) are updated regularly.	Operational data for equipment, to which mechanical services are provided by the private dealer, is updated by the dealers. On the other hand, there are occasional shortages and delays in updating the equipment status managed by MoWT and host organizations. In the future, as a means for MoWT itself to record and update operational data, it is conceivable to use the GPS tracking system installed on equipment.	also improved. On the other hand, although the GPS tracking system makes MoWT's equipment management more efficient, MoWT is expected to accumulate equipment operation records, maintenance/repair records, spare parts inventory, etc. in its own equipment ledger control system, and based on the accumulated data, MoWT will be able to further improve the efficiency of equipment management by developing a system for maintenance and repair of equipment by direct management or by the private sector, as well as the procurement of additional spare parts without delay. At present, MoWT's equipment ledger is paper-based, but it is conceivable to update it to a computer-based database ledger control system, and such a challenge is an issue to further improvement of efficiency in equipment management.
		2. Whether machines' operation data are utilized for equipment management.	Operational data for equipment, to which mechanical services are provided by the private dealer, is utilized by the dealers. Operational data of equipment managed by MoWT and host organizations is insufficient. In the future, MoWT is expected to manage operational data by using a GPS tracking system.	
	Maintenance Record	1. Whether machines' maintenance/repair data are recorded properly.	Maintenance and repair data for equipment, to which mechanical services are provided by the private dealer, is updated by the dealers. Maintenance and repair data for equipment managed by MoWT and host organizations is recorded in hard copy (paper), but it is not stored as data. MoWT needs to keep in touch with dealers to keep track of the equipment status in a timely manner.	
		2. Whether machines' maintenance/repair data are utilized for equipment management.	Maintenance and repair data for equipment, to which mechanical services are provided by the private dealer, is utilized by the dealers. The management of maintenance and repair data for equipment managed by MoWT and host organizations is insufficient. MoWT needs to keep in touch with dealers to keep track of the equipment status in a timely manner. In addition, it is desirable to share maintenance records with dealers for minor maintenance carried out by MoWT itself.	
	Spare parts inventory control	1. Whether receipts and issues of spare parts are recorded properly.	Spare parts are procured on an as-needed basis, and regional mechanical workshops keep a limited stock of parts. On the premise of continuing the above system, MoWT needs to systematically procure additional parts according to the	
		2. Whether there is proper		

		awareness of spare parts consumption (frequency of use) and quantities in inventory. 3. Whether spare parts data are utilized for equipment management.	parts inventory and operational status of equipment.	
Instructor for Operator	Inspection	1. Can he teach (coach) pre-operation inspection and closing inspection?	TOT for improving operator's capacity is carried out by the UNIDO project. The Project collaborates with the UNIDO project. The UNIDO project aims a following goal in its operator training program. ➢ MoWT master trainer: 50 persons ➢ Operator: 360 persons ➢ Youth in human development: 80 persons In addition, the UNIDO project develops a Operator Training Center in Luweero district.	Since the UNIDO project has been implementing the operator training programme in parallel with the Project, through discussions with the parties concerned at the commencement of the Project the roles to be undertaken by both projects were clarified, which means that the operator training was undertaken by UNIDO project, and the mechanic training was undertaken by JICA Project. During the Project period, progress was shared and opinions were exchanged with UNIDO project team on a regular and irregular basis, and the results were reflected in the activities of respective projects. Regarding the pre-operation and closing inspections of equipment, the inspection form prepared by the UNIDO project was reviewed by the JICA Project Team, and it was decided as the standard form based on mutual agreement. Under the UNIDO project, pre-operation and closing inspection inspections guidance is being implemented based on the said form.
	Operation	1. Can he read (understand) indications of meters and gauges properly? 2. Can he work skillfully by using equipment? 3. Can he teach (coach) how to operate equipment and how to work by using equipment?	There is room for further capacity improvement in skill. TOT for improving operator's capacity is carried out by the UNIDO project. The Project collaborates with the UNIDO project, grasps progress in UNIDO's training and give a recommendation when needed.	The operator training programme by UNIDO project is ongoing.
	Safety Work	1. Does he fully understand safety work in the construction site?	According to the MoWT Road Maintenance Management Manual, it explains as follows for example: ➢ "It is the responsibility of the maintenance foreman or supervisor to insist that	The operator training programme by UNIDO project is ongoing. In the Project, through site investigations, the Project Team gave advice on issue requiring improvement related to safety measures for a construction work as

			all risks are minimized." ➢ "Operators and laborers alike must be informed of the potential risks and of procedures for working or close to machinery." On the other hand, safety work currently depends on the knowledge and experience of individual supervisors at each site, and operators are not fully aware of the precautions to be taken when operating equipment or when parking it. Since TOT by the UNIDO project includes safety instructions, the Project collaborates with the UNIDO project and give a recommendation when needed.	much as the Team could. Regarding safety measures for a construction work, it is conceivable necessary to encourage awareness throughout the organization, from the top level of it to those who are involved in the construction work (supervisors, operators, and workers). Therefore, it is a future issue to work on systematic enlightenment education related to safety work, and to develop a comprehensive guideline that include construction accident cases, lessons learned, and introduction of specific countermeasures.
		2. Can he teach (coach) how to operate equipment safely and how to work safely?	Knowledge of hazard prediction and preventive measures depends on the site supervisor's experience. Therefore, it is desirable to standardize the knowledge and experience of supervisors on safe work as much as possible.	As mentioned above, in addition to educational activities related to safety, development of guidelines is an issue. By disseminating the guidelines widely, it is important to homogenize safe work guidance at all construction sites at a certain level or higher, and to add individual measures according to site conditions and environment of respective sites.
Instructor for Mechanic	Tools and Equipment	1. Can he manage to use (operate) mobile workshop?	The utilization of the mobile workshop is limited. It is necessary for MoWT to understand the specifications and performance of mobile workshops and to improve their capacity for maintenance of equipment, including safety work. A mobile workshop will be used as one of the teaching materials in the TOT for training equipment mechanics implemented in this project.	Through the TOT for mechanics conducted in the Project, the Project Team provided practical instructions using equipment and tools installed in the mobile workshop. This activity could make MoWT mechanics deepen their understandings about specifications and performance of mobile workshop. Regarding on-site maintenance services using the mobile workshop, it is hoped that the equipment will be actively used according to the maintenance needs around sites.
		2. Can he use tools and workshop equipment skillfully?	There is room for further capacity improvement in knowledge and skill. MoWT's regional mechanical workshops have a shortage of workshop equipment and tools, and the arrangement of them in the workshops is also inadequate. It is necessary to encourage an understanding of the necessity and handling of workshop equipment and tools.	Through the TOT for training mechanics, trainees learned how to use equipment and tools for equipment maintenance. Moreover, during the Project period, the MoWT with the assistance the Project Team procured the minimum necessary items for equipment maintenance such as measuring instruments, tools, and safety protective equipment. However, in order for MoWT to continue to train mechanics and provide equipment maintenance services, it is important for each Regional Mechanical Workshop to have sufficient equipment and tools including training equipment.

	Safety Work	1. Does he fully understand safety work in the workshop?	There is room for further capacity improvement in knowledge and skill. In particular, it is desirable to improve knowledge and skills regarding slinging for crane works. General safety education including sling work should be provided through the TOT in the Project.	Through the TOT for training mechanics, all trainees acquired a certain level of knowledge and skills related to safety work such as slinging work and equipment maintenance in general.
		2. Can he teach (coach) safety work in the workshop?	There is room for further capacity improvement in knowledge and skill. It is necessary to provide training on safety guidance for mechanics through the TOT in the Project.	As mentioned above, the trainees of the TOT acquired a certain level of knowledge and skills related to safety work. In the future, the trainees of the TOT will perform as an instructor, and the issue is to continue to conduct safey works at each MoWT's Regional Mechanical Workshop, and to disseminate it horizontally within the organization.
	Repair Work	1. Does he fully understand structure and function of the components/devices equipped for the construction equipment?	There is room for further capacity improvement in knowledge and skill. It is necessary to acquire knowledge about the structure and function of equipment by utilizing actual equipment through the TOT in the Project.	Through the TOT for training mechanics, all trainees understood the structural features and functions of equipment owned by MoWT, and learned the techniques for inspecting and maintaining the equipment. In the final test conducted at the end of TOT, the Project Team confirmed that all trainees had acquired the abilities and qualities to perform as an instructor. In the future, the issue is that the trainees of TOT of the Project will perform as an instructor and continuously work on the training of MoWT mechanics.
		2. Does he have skill to inspect and maintain/repair construction equipment?	There is room for further capacity improvement in knowledge and skill. It is necessary to implement the OJT for periodic inspection and maintenance work of equipment by using actual equipment through the TOT of the Project.	
		3. Can he teach how to inspect and maintain/repair construction equipment (theory & practice)?	There is room for further capacity improvement in knowledge and skill. It is necessary to train instructors for inspection and maintenance work by using actual equipment through the TOT of the Project.	
Manager for Equipment Management	Workshop Management	1. Can he manage workshop and spare parts store operation?	MoWT procures necessary spare parts from private dealers as it needs. In continuing utilizing private dealers, MoWT needs to procure additional parts according to the parts inventory and operational status of equipment.	It is important to continue to use private sector services provided by local dealers for operation and maintenance of equipment and procure an appropriate quantity of spare parts. Further efficiency improvement of equipment management including spare parts management can be expected by introducing a database ledger control system including spare part inventory management. On the other hand, MoWT's Mechanical Workshops have a shortage of facilities and workshop equipment for each service shop, and so the upgrading the workshop can be an issue in the future.

	Equipment Management	1. Can he manage to control repair/maintenance of construction equipment? 2. Can he carry out troubleshooting of construction equipment and give proper directions to mechanics? 3. Does he understand procurement procedure of spare parts and availability of suppliers?	The managers of MoWT's regional mechanical workshops have a certain level of ability to manage equipment, although there are some individual differences. However, it is desirable to further improve their capacity in order to operate and maintain their equipment more efficiently. It is necessary to improve equipment management capacity in cooperation with private dealers.	Based on the premise that mechanical services provided by private dealers will be used, the TOT implemented in the Project improved capacity to maintain equipment in proper manner, and the trainees of TOT were trained as future instructors. In the future, it is an issue that MoWT will continue to develop human resources by mechanic instructors under the leadership of the manager of the Regional Mechanical Workshop, and aim to improve practical skills through daily equipment maintenance work.
	Budget Management	1. Does he understand budget management (spare parts procurement and maintenance/repair of construction equipment)?	Shortage of the equipment maintenance budget has been normalized. It is necessary to give advice on the necessary budget scale for appropriate maintenance of equipment through the Project.	The Project Team calculated the annual maintenance costs over the service life of equipment owned by MoWT and explained it to MoWT. Since the scale of the above calculated costs exceeds the annual equipment maintenance budget allocated to MoWT in recent years, MoWT is recommended to pay attention to take a necessary coordination in the government in order to secure the budget.

Source: JICA Project Team

(2) Other Remarkable Issues and Lessons

In addition to the issues described at the rightmost column in Table 4-1 above, the following items are remarkable issues and lessons for MoWT to improve the efficiency of road maintenance and develop human resources by itself.

1) Operation under chronic budget shortfalls

MoWT's annual budget for road maintenance and equipment operation/maintenance has been shrinking in recent years. In particular, the financial crunch after the spread of COVID-19 is considered so serious.

For example, the annual budget for equipment operation and maintenance reduced about 50% in 2022 compared to 2019 before the spread of COVID-19. In FY2022, MoWT applied for an annual budget of US$12 million for equipment maintenance, but only US$3 million was approved.

The scale of the annual budget mentioned above is considered inadequate under the circumstances where maintenance costs for equipment which was procured from Japan will increase in the future. In the Project, after calculating the annual cost assumed to be necessary in the future for the maintenance of equipment procured from Japan, the Project Team and MoWT explained it to the officials in charge of financial affairs from MoFPED in an effort to obtain their understanding. Further coordination within the government is recommended for future budget increases.

As a matter of course, the budget scale for equipment operation and maintenance is on a downward trend, and in addition, under the circumstances where facilities and equipment of MoWT's Mechanical Workshops for equipment maintenance are inadequate and deteriorated, it is recommended to take into account the MoWT's budget scale when procurement of new equipment will be planned in the future. In the case of donor assistance for such a new procurement, it may be necessary for a donor side to take into account the MoWT's budgetary conditions and its future predict so that the scale of procurement will match the MoWT's annual budget.

2) Role as Responsible Organization for Road Administration

The District and Community Access Roads under the jurisdiction of MoWT will be transferred to the control of local governments after the completion of large-scale road rehabilitation work. Since the road maintenance equipment procured from Japan by MoWT in 2017 has been allocated to local governments, after the transfer of roads to local governments, local governments become a responsible authority for small-scale road maintenance using equipment allocated.

However, due to financial constraints for local governments and a lack of knowledge and technology regarding road maintenance, many years passed without proper road maintenance after the transfer, promoting in damage and deterioration that is difficult local governments to take a measure has been normalized.

As a result, the MoWT, which has no financial leeway, has to carry out large-scale rehabilitation work, and it results in an increase in total road maintenance costs.

In the Project, from the perspective that MoWT should show ownership as the highest organization in road administration of the country and supervise and guide local governments, the Project Team considered that it is desirable for MoWT to understands that shifting the way of thinking to asset management and preventive maintenance system would contribute to optimizing a life cycle cost of roads and horizontally disseminate to domestic road administration organizations.

At the completion of the Project, MoWT's officials at management levels expressed their intention to invite local government officials to MoWT and share the achievements of the Project and future efforts.

On the other hand, in Uganda where local roads like District and Community Access Road account for most of the length of the national road network, a system to continue small-scale and simple road inspection and maintenance involving local governments and local communities in regions is considered extremely important. Therefore, MoWT's intention to horizontally disseminate its knowledge to local governments is not a temporary one, and it is a major issue for both central and local governments to continue cooperation in the future to improve the management of roads under their jurisdiction.

3) Reform of Staff Consciousness

In order for MoWT to carry out road maintenance work with a limited annual budget, construction supervisors, equipment managers, mechanics, operators, etc. are required to understand their respective responsibilities in order to work on optimizing daily operation of owned equipment under the guidance of the management level of organization.

In particular, one of the factors is that MoWT equipment operators are likely non-permanent employees, and generally lack responsibility for daily routine inspection, cleaning, and basic maintenance of equipment as well as the operation of equipment. There are cases in which unreasonable driving operations ignoring equipment abnormalities and deformations become the norm, and as a result, repair costs increase due to equipment failures and deterioration, or cases in which repairs become impossible.

In terms of the above situation, the Project Team worked to encourage awareness of operators as one of players who are responsible for part of the equipment operation, such as by encouraging operators to inspect equipment at the beginning and end of daily work in collaboration with the UNIDO project which has been implementing the operator training programme. In addition, the Project Team created a standard format for a technical report to compile detailed equipment inspection and maintenance records so that all personnel involved in equipment (e.g. equipment managers, mechanics, and operators) can participate in preparing and sharing such reports within their respective scope of work. The Project Team worked to establish a reporting structure as part of daily work so that all players could continue to be involved.

In the future, especially regarding equipment operators, their supervisors will be required to train and guide them on the premise that operators will be replaced because of their employment status.

4.3 Proposed Future Assistance

Table 4-2 shows the proposed future assistance in the field of road maintenance.

Table 4-2 Proposed Future Assistance

Item of Assistance	Background	Outline of Assistance
Technical Cooperation for Capacity Development in Road Maintenance	Upon the completion the Project, the following outcomes was achieved i. The Project obtained MoWT's understanding that rationally assessing the necessity and urgency of road maintenance based on regular and irregular inspections, and shifting to the preventive maintenance system on the assessment results would contribute to reducing the long-term maintenance costs of roads. ii. The Project established a system in which the civil team (i.e. Department of Roads and Bridges) and the mechanical team (i.e. Department of Mechanical Engineering Services) cooperate to grasp the status of equipment and improve improper use. iii. The Project defined the scope of mechanical services to be shared with the private dealer in operation and maintenance of equipment to continue using private sector services. In addition, the Project developed a standard format for a technical report to appropriately and precisely report equipment maintenance and repair records within the MoWT organization and with local dealers. iv. The Project developed instructors for future training of MoWT mechanics as well as a training plan which can be conducted by MoWT itself. Based on the above achievement from the Project, the following challenge are important for MoWT to further improve its capacity and efficiency of road maintenance. ➢ To promote shifting to the preventive road maintenance to reduce long-term maintenance costs. In this regard, it is considered effective to utilize the existing local road database of MoWT in selecting roads to be maintained, and the said existing database may be updated as necessary for operation. ➢ To develop a ledger control database system to further efficient operation and maintenance of equipment.	Based on the background as mentioned, the following technical cooperation for further improvement of road management and maintenance by MoWT is conceivable. a) To grasp an issue on operation of the Database System for District and Urban Roads developed in the past JICA technical cooperation, and upgrade and technical assistance for proper operation. b) To assist to develop a ledger control database system for road maintenance equipment for further efficient operation and maintenance by MoWT in collaboration with a private sector. c) To establish a solidarity between the road maintenance work by the civil team and equipment management by the mechanical team in actual practices of above a) and b) through implementing a series of pilot project. Regarding the activities a) to c) mentioned above, a) is an effective means for the Department of Roads and Bridges to improve routine work related to a planning and budgeting for road maintenance and rehabilitation, and b) aims to further improve the efficiency of equipment management by the Department of Mechanical Engineering Services. By providing comprehensive assistance with both a) and b), the functions and operational efficiency of MoWT as a road administrator is able to be improved comprehensively, and eventually such assistance will contribute to the optimization of the life cycle costs of both roads and equipment. Regarding a structure related to road facility such as a box culvert and small-scale bridge under the control of MoWT, an area of road facility to be targeted in the technical cooperation needs to be determined.
Upgrading the Central Mechanical Workshop and Assistance for Functional Enhancement of the Regional Workshop	The Project defined the scope of mechanical services to be shared with the private dealer, and conducted capacity development for equipment maintenance. In order for MoWT to operate and maintain road equipment appropriately and efficiently based on the above achievements, it is considered necessary to upgrade the existing mechanical workshop in the future.	For functional enhancement of the Kampala Central Workshop in order to perform as a head quarter in management of road maintenance equipment, the following assistance is conceivable. a) Improvement of a workshop building and equipment of the Central Mechanical Workshop b) Capacity enhancement for functions as a head quarter Although functional enhancement of existing regional workshops such as Gulu (Northern Region) and Mbarara (Western Region) is also

		conceivable, it is necessary to define a role between the central and the regional workshop and consider the project component including the undertakings by the recipient country.

Source: JICA Project Team

END

Appendix

1. Work Plan
2. Attendance List
3. Organization Structure of the Department of Roads and Bridges, and the Department of Mechanical Engineering Services
4. Implementation Schedule (Plan/Actual)
5. Presentation Material for the Final Workshop
6. Recommendations

Appendix 1. Work Plan

ADVISOR FOR CAPACITY DEVELOPMENT IN ROAD CONSTRUCTION AND MAINTENANCE IN THE REPUBLIC OF UGANDA

WORK PLAN

APRIL 2021

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

YACHIYO ENGINEERING CO., LTD.

Project Location Map

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Project Location Map

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1. Outline of the Project

1.1 Background of the Project

In August 2019, the Government of the Republic of Uganda (hereinafter referred to as Uganda) submitted a request to the Government of Japan for technical cooperation aimed at improving the policy making and planning capacity for road construction and maintenance managed by the Ministry of Works and Transport (hereinafter referred to as MoWT), improving road construction and maintenance systems, developing human resources for the proper utilization of road equipment. In response to this, the Japan International Cooperation Agency (hereinafter referred to as JICA) decided to dispatch a technical expert team (hereinafter referred to as the "Project Team") to implement the Technical Cooperation (hereinafter referred to as the "Project").

This work plan was prepared by the Project Team to explain the goals, outcomes, outlines of the activities, etc. of the Project to the government officials of Uganda, and to obtain a sufficient understanding of the basic contents of the Project by the Uganda side.

1.2 Member of the Project Team

The members of the Team are as follows:

Table 1-1 Member of the Project Team

Name	Organization	Assignment
Isao TAKAHASHI	Yachiyo Engineering Co., Ltd.	Team Leader / Road Management Plan： ➢ Project Management ➢ Assistance for improving the capacity for policy making and planning for road construction and maintenance ➢ Assistance for improving road construction and maintenance systems
Etsuo HASHIGUCHI	Yachiyo Engineering Co., Ltd.	Road Construction/Maintenance Equipment Management： ➢ Technical assistance for proper utilization of road equipment

1.3 Itinerary

The proposed itinerary is shown as follows:

Table 1-2 Proposed Itinerary

Year/Month	2021										2022												2023		
	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
Team Leader / Road Management Plan：Isao TAKAHASHI																									
Road Construction/Maintenance Equipment Management：Etsuo HASHIGUCHI																									

Note: Above itinerary for each assignment of the Project Team can be rescheduled according to discussion among all parties (i.e. MoWT, JICA and the Project Team).

2. Implementation Policy

2.1 Basic Policy for Project Implementation

2.1.1 Background and Objectives

Uganda plays a key role in linking the Republic of Rwanda, the Democratic Republic of the Congo and the landlocked countries and regions surrounding the Republic of South Sudan to the Indian Ocean coastal states of the Republic of Kenya and the United Republic of Tanzania. As the linkages between these surrounding regions and countries as economic zones have been strengthened and regional trade is revitalizing, the development of road networks within the region is a crucial for the entire region. Moreover, since the main industry of Uganda is agriculture and the rural population is approximately 80% of the nation's population, securing stable transport functions for agricultural products both domestically and abroad is indispensable for the economic development of Uganda.

On the other hand, since road transport accounts for about 96% of Uganda's transport needs, domestic transport and socio-economic activities are mainly carried out along the road network. Therefore, it is essential that sufficient maintenance and improvement work of the road is sustained. Meanwhile, among the 159,366km total road length network composed of of national road under the jurisdiction of MoWT (about 20,854km), district road (about 38,603km), urban road (about 19,959km), and community access road (about 79,947km), the pavement ratio is only about 4% of the total. And sound maintenance and management of the road network is a challenge in service delivery.

In light of this situation, in 2012 the government of Uganda, with a loan of approximately US$100 million from the Export-Import Bank of the Republic of China procured more than 1,405 road equipment from China and distributed it to local administrative agencies for the construction and maintenance of rural roads. However, after the distribution of China's equipment to rural areas, many of the equipment and materials were left unused because of various problems such as (1) insufficient technical level of road engineers and equipment operators, (2) insufficient budget allocation for road maintenance and equipment maintenance and (3) insufficient equipment specifications for target construction types.

Subsequently, in 2014, the government of Uganda procured 1,152 more durable road equipment (650 road equipment and 502 vehicles) from Japan with a 17.8 billion Japanese yen financing from the Japan Bank for International Cooperation and the procurement equipment was distributed to local authorities in 2017. In the procurement and delivery of Japanese equipment and materials, continuous service provision activities were implemented such as initial operation trainings to equipment managers and operators by the supplier and manufacturers, and operation status monitoring after equipment arrangement. However, while the two-year warranty period after the procurement of equipment has already expired, the shortage of skilled road engineers and the lack of technical level of equipment and plant operators, mechanics, etc. have not been resolved.

Based on such background, the government of Uganda requested the Japanese government for technical cooperation aimed at improving policy making and planning capabilities for road construction and maintenance, improving road construction and maintenance systems and developing human resources for the proper use of road equipment.

In light of the above-mentioned request, the Project aims to develop expected outcomes and achieve the project goals by implementing activities 1-1 to 3-2 shown in Table 2-1.

Table 2-1 Project Goals, Expected Outcomes and Outline of Activity

Project Goals	MoWT personnel improve their capacity in the fields of road construction and maintenance.
Expected Outcomes	Outcomes 1: Improvement measures for policy making, planning, and budgeting for road construction and maintenance of MoWT are proposed. Outcomes 2: A system for road construction and maintenance, including effective use of road construction equipment, of MoWT is improved in visible achievement of proper road construction/maintenance works for fair/good conditions. Outcomes 3: Capabilities of MoWT's road engineers, operators and mechanics through road construction/maintenance and use of equipment is strengthened.
Outline of Activity	Activity 1-1: To evaluate and analyze current systems for policy making, planning and budgeting related to road construction and maintenance, then to advise and recommend areas for improving the system. Activities 2-1: To assess and analyze current systems for road construction and maintenance including effective use of road construction equipment, then to train and advise for improving the system. Activity 3-1: To evaluate and analyze current issues of human resources, such as road engineers, operators and mechanics, in charge of road construction and maintenance, and the current status of equipment use/management, then to train and advise personnel for the appropriate utilization and management of equipment. Activities 3-2: To develop a future improvement plan based on the issues identified through Activities 3-1 above.

2.1.2 Basic Issues on the Project

In 2012, the government of Uganda changed its policy of road improvement and maintenance from the private outsourcing system to the direct management system called a force account for some road construction and maintenance except for national road development, etc., and the road project has been developed by MoWT based on the force account guidelines. In recent years, the government of Uganda procured a large amount of road construction equipment through several past projects described in "2.1.1 Background and Objectives", but due to technical shortages among MoWT’s road engineers, operators, mechanics, etc., such equipment owned tends to be poorly maintained leading to malfunctioning. In addition, the development and maintenance of roads have not been promoted sufficiently because of multiple factors such as the inappropriate system including planning and budget formulation for systematic road works and effective utilization of equipment. Especially, in the case of district roads, cases of defective maintenance on existing roads, such as stripping of existing asphalt pavement, exposure of base course, etc., are observed. In many cases, early deterioration is attributed to problems in the design or construction stage and further, one of the main factors is that the system of appropriate maintenance cycles after service has not been developed.

The Project aims at improving the basic capabilities of MoWT, as the counterpart (hereinafter referred to as "C/P"), for road construction and maintenance, as well as for the appropriate operation and maintenance of equipment. Especially, through the activities shown in "Outline of Activities" of Table 2-1, it is important for the C/P and other related organizations in Uganda to develop the ownership necessary for road projects and long-term operation of equipment, to carry out technical transfer at the basic level necessary for continuing the self-development of personnel such as operators and mechanics, and to examine further support programs in the future as necessary.

In order to achieve the project goals under the issues described above, the Project Team has proposed the advisor(s) to be dispatched to Uganda and major activities in each assignment as follows:

Table 2-2 Member to Travel and Major Activities

Item	Advisor(s)	Major Activities
1st Assignment	- Takahashi - Hashiguchi	Explanation, discussion and decision of work plan, grasp of present status, arrangement of problems, start of training, etc.
2nd to 4th Assignment	2nd and 4th: - Takahashi, except 3rd assignment - Hashiguchi	Interim feedback, practical training (OJT) for trainees, workshop opening, interim achievement evaluation, etc.
5th Assignment	- Takahashi - Hashigushi	Interim feedback, practical training (OJT) for trainees, workshop opening, final achievement evaluation, final reporting and recommendation, etc.

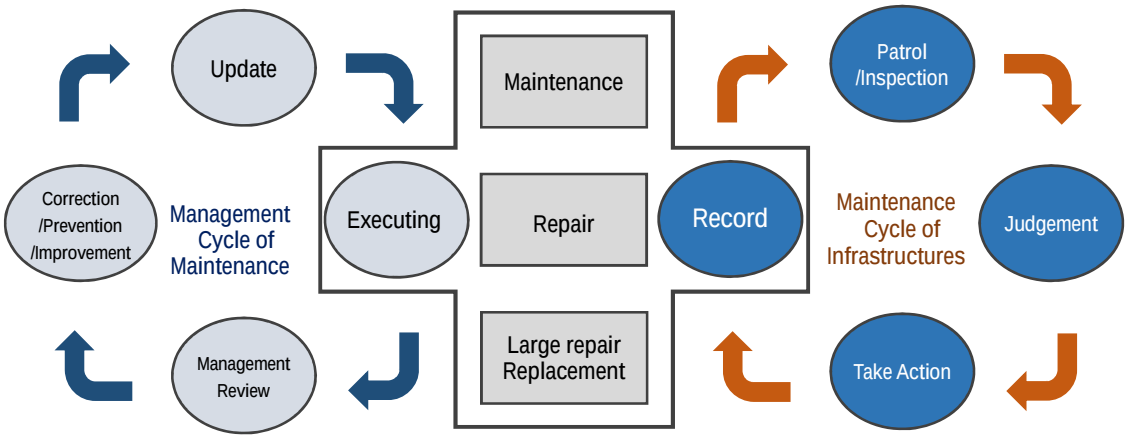
The details for above activities and means of implementation is described in "2.2.3 Activities for Outcomes".

2.1.3 Technical Policy for the Project

Notable policies from a technical point of view are described in the following (1) to (5).

(1) Support for improvement in policy, planning and budgeting

Through improving capabilities for a new construction and maintenance work, it is crucial to optimize a series of Asset Management Cycles: Survey and Planning, Design, Construction, Maintenance and Upgrading, in the long-term management of roads. Therefore, we propose improvement measures using the conceptual diagram of the Asset Management System shown in Figure 2-1. In order to properly operate these, it is crucial to continue the two cycles of organizational management assuming MoWT Central Organization (PDCA Cycle) and on-site management assuming the activities of local organizations. We will identify the causes of the current issues and consider remedial measures based on the intentions of the C/P. For example, if there are problems with the operation of site management for maintenance, inspection/repair, and renewal of district roads, proposals will be made based on PDCA cycle of organizational management, such as the creation of a system to realize effective improvement measures, and the formulation of policies and plans including budget formulation.

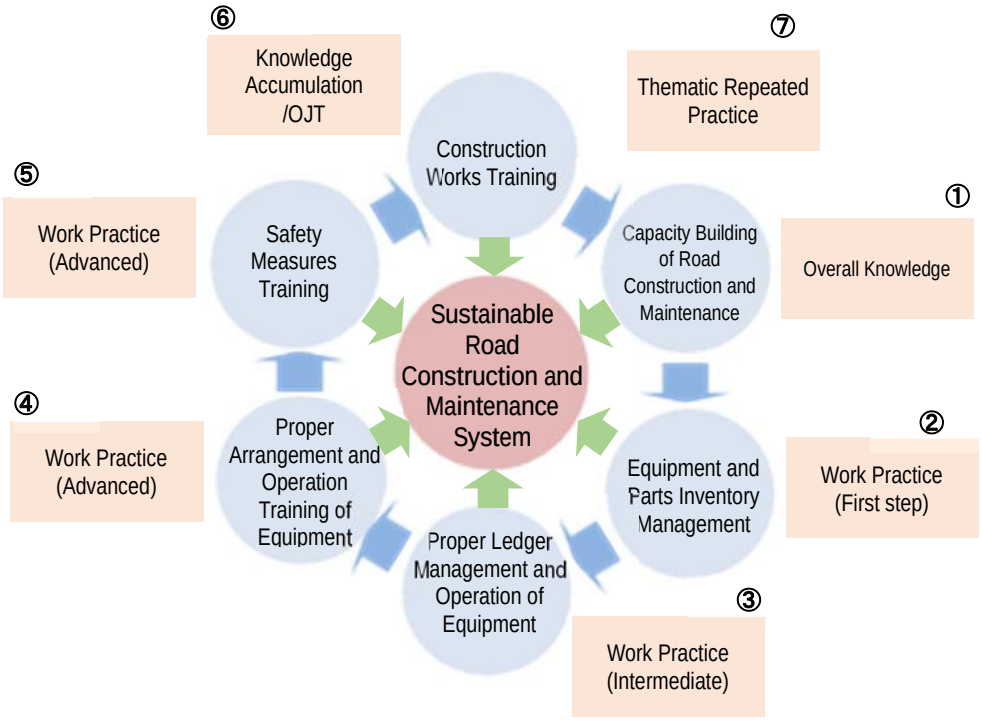


Source: Prepared by the Project Team

Figure 2-1 Conceptual Diagram of Asset Management System

(2) Support for improvement of road improvement and maintenance systems

The system of road improvement and maintenance in MoWT and related organizations, personnel assignment, business flow, and present state of road equipment utilization are grasped, and problems are analyzed. In order to effectively utilize the road equipment owned by MoWT and implement road improvement and maintenance appropriately and continuously, it is necessary to improve the Ministry staff capacity by repeatedly conducting training in various aspects such as maintenance of equipment (including parts inventory control), equipment operation by ledger control, proper arrangement and operation of equipment, work safety measures, and construction capacity, and to establish a work flow for road improvement and maintenance consisting of these aspects. Figure 2-2 shows technical support items and flow for the construction of sustainable road improvement and maintenance systems.

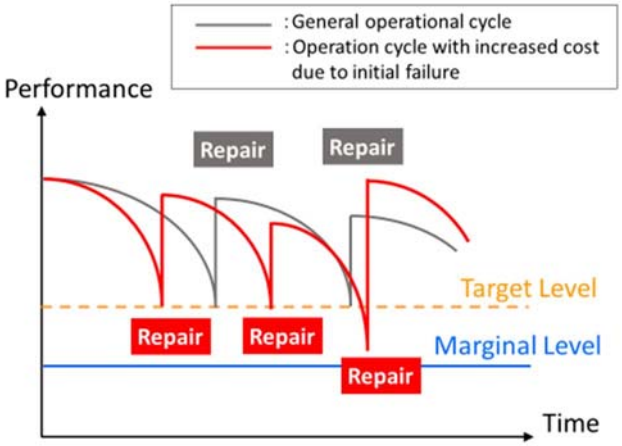


Source: Prepared by the Project Team

Figure 2-2 Technical Support Items and Flow for Building a Sustainable Road Construction and Maintenance System

In addition, in the course of providing technical guidance for a series of road improvement and management systems based on Figure 2-2, after confirming the operation status and issues of the database developed under the " District and Urban Roads（DUR）Mapping and Roads Database Project (2015)", information update of the database and proposals for improvement as necessary will be made through the Project.

In developing countries in general including the East African region, deterioration of roads tends to be accelerated due to initial failures in the construction stage, such as improper material selection in subgrade and subbase course construction and asphalt pavement construction, contamination of materials with foreign matter, insufficient rolling pressure and poor finish after material laying and leveling. Such a tendency causes an increase in the cost of maintenance and repair work after construction, resulting in a insufficiency of the budget for road improvement and maintenance, as well as for the operation and maintenance of equipment (see Figure 2-3). Based on the above, the Project first verifies the type and cause of initial defects together with C/P, and second recognizes the fact that initial road improvement and maintenance are integral in the entire operation cycle in common with C/P. Third, it supports the preparation of construction plans (including construction methods, materials used, personnel and equipment, execution processes, quality control items, and points requiring attention in construction) that are required to mitigate initial defects. And advise on budgetary measures.



Source: Prepared by the Project Team

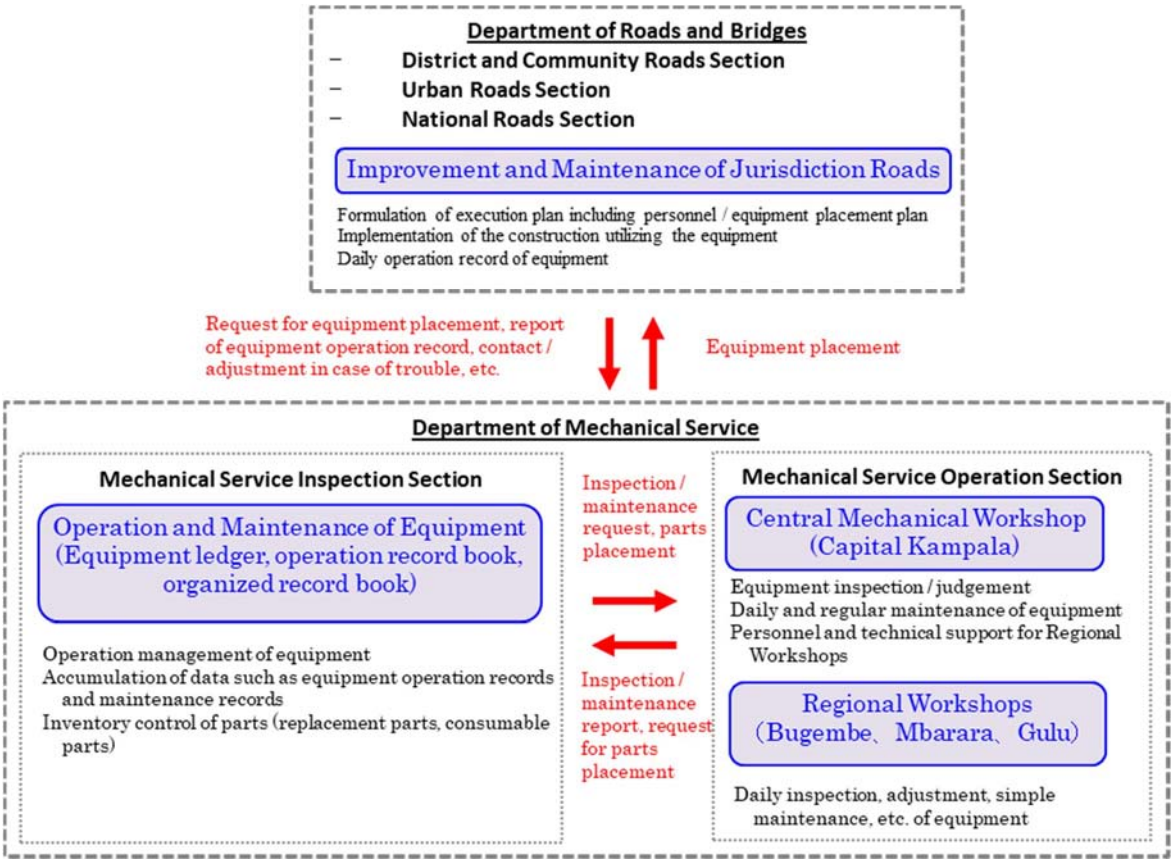
Figure 2-3 Conceptual Diagram of Road Operation Cycle

(3) Support for capacity building of road engineers, operators, mechanics, etc. through road equipment

In assisting road engineers, operators, mechanics, and others in MoWT and related organizations, it is essential to provide comprehensive technical support from the following perspectives: (1) proper equipment operation through the cooperation of road engineers and equipment managers; (2) capacity building of mechanics and operators; and (3) appropriate use of private services. Following are the implementation policies for each of the above (1) to (3).

1) Proper equipment operation through cooperation between road engineers and equipment managers

In the equipment operation and maintenance of MoWT, the Central Mechanical Workshop in Kampala City is used as the base, and the Regional Workshops are deployed in three domestic locations in Bugenbe, Mbarara, and Gulu. The equipment management operation system is established by a series of work flow with each department in charge of the Department of Mechanical Service responsible for the operation and management of equipment, and with the Department of Roads and Bridges responsible for the construction and maintenance of the roads. Figure 2-4 shows the operational flow chart of road improvement, maintenance and equipment operation by these related departments.



Note: This Flowchart is the only tentative draft proposed by the Project Team and practicable flow for effective operation is to be discussed with MoWT through the Project.

Source: Prepared by the Project Team

Figure 2-4 Flowchart of Road Improvement, Maintenance and Equipment Operation (Draft)

In the Project, the final work flow will be established after repeatedly reviewing the applicability of the above flow. In addition, an operation manual will be prepared to properly execute operations based on the same flow. In addition to these central and regional maintenance plants, MoWT provides guidance and advice on joint use of equipment with regional centers by deploying Zonal Centre located in nine locations throughout the country.

2) Strengthening of equipment maintenance system

Of the maintenance workshops of MoWT owned equipment, the Bugenbe the Regional Workshops was renovated with a grant aid in 1996, but the functions of buildings and maintenance equipment are limited in all maintenance workshops including the Central Mechanical Workshop. Therefore, it is in a situation where sufficient service cannot be provided for maintenance and repair of the equipment in possession.

Source: Photographed by the Project Team

Figure 2-5 Mobile workshop (reference)

Based on the above, in order to properly maintain and repair equipment in a timely manner and to operate owned equipment in a sound manner over its useful life, it is desirable for the medium to long term to proceed with the construction and renovation of buildings at existing maintenance workshops and the enhancement of maintenance equipment. Meanwhile, the Project intends to make full use of the mobile workshop (see Figure 2-5) procured by Japan's aid in 2017, in order to respond to the need for highly urgent equipment maintenance in the short term and to foster personnel for operators and mechanics. The mobile workshop is the equipment which enables the business trip service by the rolling stock equipped with basic maintenance equipment and tools. Therefore, we will support in improving the efficiency of equipment maintenance and repair by utilizing the equipment after organizing the arrangement of the equipment, its utilization status and operational problems.

Meanwhile, mechanics are the basis for guidance on this equipment. However, in order to share the actual situation of equipment repair caused by improper equipment operation during construction, we will propose the participation of operators in this training on maintenance equipment as necessary.

3) Appropriate use of private services

Recently, the latest construction equipment manufactured by manufacturers in Japan, Europe, U.S.A. and other developed countries has been changed from conventional mechanical equipment to computer control system. by the development of the electronization technology. As such computerized control progresses, not only is the response by users inefficient for maintenance, repairs, and maintenance above a medium-scale level that exceeds a simple level, but there is also a risk of deteriorating the condition. Especially in the equipment in which the computer control system is introduced, it is important that the user confirms the maintenance level and appropriately utilizes the service of manufacturers and/or distributors.

Table 2-2 shows maintenance and repair implementation categories with the private sector, which are considered desirable in view of the facilities and personnel systems of MoWT existing facilities. The implementation category will be optimized as appropriate through consultations with the C/P based on the local private service system.

Table 2-2 Maintenance and Repair Implementation Categories with MoWT and Private Sector (Draft)

Service level	Type of equipment servicing and repair	Main work items	Demarcation		
			MoWT		Manufacturer / Designated Local Dealer
			Central Mechanical Workshop	Regional Workshops	
1 Light	Periodical Maintenance	Change lubricants, lubrication	○	○	
2	Inspection and adjustment	Adjusting brake, adjusting clutch etc.	○	○	
3	Minor repair and maintenance	Replacement of consumable parts	○		
4	Overhaul of the main component	Engine, clutch, transmission, hydraulic component etc. (mechanical component/device)	○		○ (precision component)
5	Trouble shooting and repair of electronic component /device	Electric/electronic/hydraulic control system, for engine, power train and hydraulic component etc.			○ (Inspection, trouble diagnose, and repair)
6 Heavy	Major overhaul and repair, and modifications	Major overhaul/repair of equipment and modifications			○

Source: Prepared by the Project Team

Equipment procured through Japan's aid in 2017 also partially comprises equipment that has introduced a computer control system. For this reason, the relevant equipment will be reflected in the Project after exchanging opinions in detail, especially on the future service development of local distributors.

(4) Induction of C/P Ownership

In order to respect the independence of Uganda-related organizations, a seminar will be held by each department in charge as shown in Figure 2-4 above to understand a series of practical processes related to road improvement and maintenance, as well as the operation and management of equipment. And joint workshops will be held at the time of each trip to incorporate on-the-job training (OJT) such as joint tours in addition to lectures, and attention will be paid to continual process-improvement through PDCA cycling. Table 2-3 shows the outline of activities in seminars and workshops held by the Project.

Table 2-3 Outline of activities in seminars and workshops

Item	Subject Person	Purpose/Events	Timing, Location and Methods of Implementation
Seminar (General Meeting)	C/P personnel, road engineers and equipment managers	Purpose: Arrangement of issues related to technology transfer Items to be implemented: (1) Conceptual explanation of the asset management system (2) Budget formulation and road improvement results and review based on road policies and plans (3) Technical issues based on cases of damage to existing roads, example of equipment arrangement during maintenance and repair (4) Introduction of examples of appropriate control items using the equipment management system (5) Issues with current road improvement and maintenance systems (6) Current technical problems in the operation and	Timing: First Assignment (Provided, however, that (1) shall be implemented from time to time during the project period.) Location: MoWT Methods: Meeting and opinion exchange including expert lectures

		management of aircraft (including equipment ledger management), and problems in the operation system (7) Discussion on measures to respond to the issues mentioned in (5) and (6) above	
1st to 4th times Joint Workshop	C/P staff, road engineers, equipment managers, instructors (operators and mechanics)	Purpose: Cross-sectional training sessions with the participation of departments in charge will enable organizations to understand the practical processes of road maintenance and equipment operation and create ownership. Items to be implemented: (1) Explanation of the scope of work and reporting of activities by each department (2) Technical Issues in Road Development and Maintenance (3) Technical problems in the operation of the equipment management system (4) Problems in cooperation between the departments in charge of construction and the departments in charge of equipment (e.g., proper arrangement of equipment to construction sites, timely reporting of daily operation records of road equipment, etc.) (5) Joint inspections of construction sites, plants, etc. around Kampala City (6) Joint inspection of Kampala Central Mechanical Workshop (7) Extracting requests and exchanging opinions from departments in charge (8) Sharing of improvement issues until the next workshop	Timing: Second to Fifth Assignment (Hold at least once per trip and hold additional as necessary) Location: Kampala Central Mechanical Workshop Methods: Joint participation-type training sessions and joint inspections
Equipment Management Workshop	Equipment managers, instructors (operators and mechanics)	Purpose: Checking the progress of equipment guidance and evaluating the degree of achievement Items to be implemented: (1) Report on the status of equipment ledger management (2) Lectures on the planning and implementation of the maintenance and management cycle of road equipment and the timing of procuring spare parts (3) To extract requests and exchange opinions (4) Sharing of improvement issues until the next workshop	Timing: Held as appropriate according to the progress of equipment guidance for each trip Location: Kampala Central Mechanical Workshop (Regional Workshops as required) Methods: Participatory training sessions

While the Project Team is not present in Uganda, the activities for the next dispatch and the tasks to be addressed until the workshop is held will be set up, and the C/P will devise ways to acquire technology and database operation know-how by exercising its ownership.

(5) Implementation of Training of Trainers

In order to achieve Outcomes 2 and 3, the Project Team assists MoWT to provide continuous and effective technical trainings for enhancing personnel competence. For the effective implementation of such trainings by MoWT, the Project Team conducts the training of trainers (TOT) who perform as the trainer in MoWT as well as the enhancement of the training system.

Technical support activities related to Outcomes 2 and 3 will be conducted using lectures, practical training, seminars, and OJTs in conjunction with PDCA cycling processes. The Project Team considers in the Project to coordinate with the "Project for Development of the Construction Equipment Operator Training Centre (Grant Aid)" being promoted by the United Nations Industrial Development Organization (UNIDO) since

August 2019 in developing the training curriculum and to share information with the said project.

Table 2-4 shows the content of training and TOT for capacity building.

Table 2-4 Contents of Training and TOT

Contents of Implementation
➢ Recommend the introduction of the equipment management system by utilizing database to enhance and to improve efficiency in managing construction equipment. (e.g. Inventory of Equipment, Operation Record, Maintenance Record, Spare Parts Inventory Control) ➢ Study and grasp staff training system in MoWT (organization structure, composition of staff, facility, budget, management of training system, curriculum, capacity of the instructors etc.) , and carry out technical transfer (TOT) to improve capacity development operation for MoWT personnel. ➢ TOT participants (candidates of master instructor) shall be selected through recommendation by MoWT and interview by the Project Team. ➢ TOT for instructors will be carried out by means of lecture, seminar/workshop and OJT. ➢ During the period when the member of the Project Team is not available, staff training operation shall be carried out continuously by MoWT counterparts (C/Ps). ➢ Carry out simple TNA for selected TOT participants and preparation of TOT curriculum. ➢ Survey possibility of outsourcing TOT (short course) by local construction equipment dealer (by PPP). ➢ Training of construction equipment operators/instructors shall be carried out in coordination with the Equipment Operator Training Centre Project that is ongoing and undertaken by UNIDO.

2.1.4 Operational Policy of the Project

Notable policies for good operation under the Project are described in the following (1) to (2).

(1) C/P and consensus-building with relevant localities

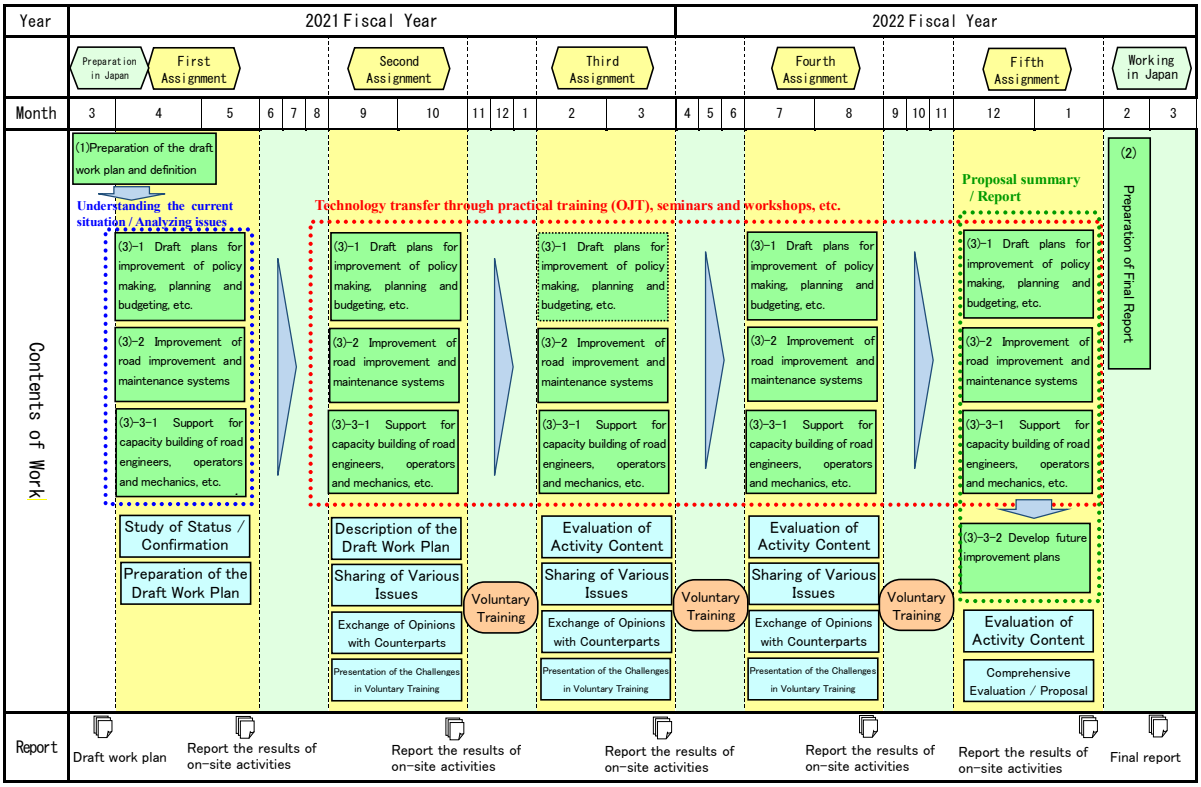
In implementing the Project, in addition to the Department of Mechanical Services department responsible for the operation and maintenance of MoWT owned equipment, road engineers of the Department of Roads and Bridges responsible for construction and maintenance of roads are also the main trainees. Therefore, in order to smoothly conduct various training activities, it is important to explain the work plan and the progress of the training to the higher level of such departments and to make an agreement among the parties concerned.

(2) Activity under the spread of COVID-19

Since the spread of COVID-19 is not subsiding, all members need to adhere to the Ministry of Health Standard Operating Procedures such as proper wearing of masks, hand washing/hand sanitizing, maintaining social distancing (min 1m, preferably 2m), etc.

2.2 Method of Implementation

The flowchart of work implementation is shown below.



*The work process is based on the PDCA cycle and technology transfer to the counterparts is carried out appropriately.
*During the period when the experts work in Japan, the trainees conduct voluntary training activities and the experts are supposed to be monitoring their activities.

Figure 2-6 Flowchart of Work Implementation

2.2.1 Work Plan Preparation and Finalization

Through analysis and examination of the Application Form submitted by MoWT in August 2019 and related materials (national development plans, reports of past projects, etc.), the Project Team grasps the whole picture of the Project. Then, the Project Team drafts the Work Plan describing the basic policy, method of project implementation work schedule, etc.to explain it to MowT. The draft Work Plan needs to be finalized through a series of discussion with concerned parties.

2.2.2 Final Report

In conjunction with the contents of all activities in the entire project period and outcomes leading the project goals, the Project Team prepares a final report describing recommendations for future road management and operations by MoWT as well as issues and lessons left, if any.

2.2.3 Activities for Outcomes

The Project Team conducts the following activities in each of the first to fifth assignment in order to achieve

each outcomes efficiently. (The descriptions in parentheses indicate the methods and means of implementation.)

First Assignment

- Explanation and discussion of draft work plan (general meeting with C/P)
- Current road policy and planning, budget formulation and budget procedure flow, and identification and analysis of organizational issues
  (Collection and interview of materials such as medium-and long-term development plans, budget results and procedure flows, MoWT and organizational structure charts of relevant organizations)
- Identification and analysis of issues related to road improvement and maintenance systems
  (Organization, facility, budget, guideline of force account, confirmation of personnel and equipment arrangement results, current problems)
- Identification and analysis of issues related to the operation and maintenance of road equipment
  (Investigation of the current status of organization, facility, budget, existing facility "Central Mechanical Workshop and Regional Workshops" confirmation of the state of maintenance of equipment management system, "Equipment ledger, equipment operation record, equipment inspection record and maintenance record, etc." including the existing equipment management ledger investigation of the present status of local equipment agency questionnaire survey and exchange of opinions on the working environment to operator and mechanic. Implementation of OJT related to improvement of equipment management system, such as introduction of database, if necessary.)
- Technical level assessment of road engineers, operators and mechanics, as well as selection of operators and mechanics instructor candidates
  (simple paper test, inspection of actual work)
- Check whether there is a human resource development system in MoWT for operators, mechanics, etc.
  (It is proposed to introduce a training system for equipment mechanics and equipment operators if no human resource development system is available.)
- Started training and held seminars
  (Practical training and joint seminars for C/P staff, road engineers, and equipment managers)
- OJT for urgent issues
  (Instruction of road improvement plan "personnel and equipment arrangement plan", safety measures for construction and instruction of safe work and operation of equipment, improvement of equipment management system, instruction of maintenance and repair of equipment, etc.)
- Providing Challenges Up to the Next Assignment
  (Issues: Establishment of construction and process plans according to annual plans for road maintenance, improvement of equipment management systems)

Second to fourth Assignments

- Confirmation and evaluation of the results of previous activities and subsequent voluntary activities
  (Improvement of road construction record, equipment management system "maintenance of equipment ledger, equipment operation record, equipment inspection record and maintenance record book, etc.")
- Confirmation and evaluation of project progress and budget formation status based on road policies and plans
  (Confirmation of statistical data such as road improvement results and budget results, and monitoring of actual results in light of plans)
- Technical instruction of road improvement and maintenance
  (Practical instruction to road engineers and operators through road construction and instruction of safety measures for construction work)
- Technical instruction related to the construction and operation of equipment management systems
  (Maintenance of equipment ledger, equipment operation record, equipment inspection record and maintenance record book, etc.)
- Technical instruction (lectures and practical training) for instructors [operators and mechanics]
- Holding of workshops and evaluation of outcomes
  (Joint participatory training sessions with the participation of C/P staff, road engineers, equipment managers, operator instructors and mechanics instructors)
- Providing Challenges Up to the Next Assignment
  (Issue Items: Accumulation of records in the equipment management ledger, equipment inspection, accumulation of diagnostics and maintenance records, record of equipment operation record and construction record including asphalt plant, etc.)

Fifth Assignment

- Confirmation and evaluation of results of voluntary activities since the last assignment *Implementation methods and means are the same as those of the above-mentioned second to fourth assignments
- Technical instruction related to road improvement and maintenance* Implementation methods and means are the same as those for the above-mentioned second to fourth assignments
- Technical instruction related to the construction and operation of equipment management systems* Implementation methods and means are the same as those for the above-mentioned second to fourth assignments
- Technical instruction for instructors [operators and mechanics] * Implementation methods and means are the same as

those for the above-mentioned second to fourth assignments
- Workshop held and final outcomes evaluation * Implementation methods and means are the same as those for the above-mentioned second to fourth assignments
- Follow-up training
  (Individual follow-up for each training target)
- Following proposals and improvement plans
  - Proposal for appropriate policy/planning and budget formulation
  - Proposal improvement for road improvement and maintenance database
  - Establishment of improvement plans and proposal for the continued proper use, operation and maintenance of road equipment

  (Summary of proposals based on the survey and training results throughout the project, and explanations and discussions at the C/P meeting)
- Final Reporting Meeting (General Meeting with C/P)

In addition, the important points to be considered especially for each outcome are shown below.

(1) Activities for Outcome 1

Table 2-5 shows the items that the Project Team need to study to identify and analyze the current status of policies, plans and budgets for road construction and maintenance.

Table 2-5 Items of Study

Category	Items of Study
Policies	➢ Checking “Uganda Vision 2040”
Plan	➢ Review and confirmation of performance of the second five-year national development plan (2015/16-2019/20) ➢ Confirmation of the Third Five-Year National Development Plan (2020/21-2024/25) and feasibility evaluation in light of the results of the Second Plan
Budget Formulation	➢ Confirmation of annual budget and performance breakdown (composition: UNRA, URF, KCCA, District, Municipality, Town Council, etc.) of Uganda Highway Fund (Uganda Road Fund) and appropriateness assessment of distribution ratio in light of past results

*UNRA: Uganda National Roads Authority, URF: Uganda Road Find, KCCA: Kampala Capital City Authority

Through the Project, the validity of these items are analyzed and shared with the C/P, and then advice and proposals are made for future policy making, planning and budget allocation.

(2) Activities for Outcome 2

In order to improve road construction and maintenance and equipment operation capabilities in MoWT and related organizations, the Project Team repeatedly conducts the OJT and workshops through the cycles shown in Figure 2-3 "Technical Support Items and Flow for Building a Sustainable Road Construction and Maintenance System". In addition, the Project Team intends to support MoWT to update the existing road database and also to propose to improve database operation as necessary.

(3) Activities for Outcome 3

In order to analyze the current capacity of road engineers, operators, mechanics and other technical personnel of MoWT and related organizations, as well as the utilization and management status of existing road equipment, the Project Team evaluate items shown in Table 2-6 and shares the issues to be improved through the Project with MoWT.

Table 2-6 Evaluation Items and Confirmation of Current Contents

Evaluation Items		Confirmation of Current Contents
Road Construction and Maintenance	Road Construction and Maintenance Work	1. Can he prepare or understand a construction plan (methods, materials, personnel and equipment, execution processes, quality control items, safety measures, points to be noted in construction, etc.) that meet the site condition?
		2. Can he carry out the works according to the construction plan?
		3. Can he provide adequate instruction and management to equipment operators and workers?
		4. Can he share information on the operation status of equipment at the site, the presence or absence of defects, etc. with the Central Mechanical Workshop and the Regional Workshops in a timely manner?
		5. Can he manage to control placement and operation of construction equipment?
	Road Inspection, etc.	1. Can he appropriately carry out daily and periodic inspections of roads under jurisdiction, emergency inspections after disasters, etc.?
		2. Can he accurately report based on the inspection results the damage and deterioration status of roads?
		3. Can he understand the necessity and urgency of repair plans according to the extent and extent of damage and deterioration?
Construction Equipment Management	Inventory of Equipment	1. Whether basic data of the equipment type, registration number, basic specification (type, maker, model, manufacturing year, serial No., capacity, engine output, purchase price, etc.) are recorded and machines' conditions are updated.
		2. Whether machines' data are utilized for equipment management.
	Operation Record	1. Whether machines' operation record (data) are updated regularly.
		2. Whether machines' operation data are utilized for equipment management.
	Maintenance Record	1. Whether machines' maintenance/repair data are recorded properly.
		2. Whether machines' maintenance/repair data are utilized for equipment management.
	Spare parts inventory control	1. Whether receipts and issues of spare parts recorded properly.
		2. Whether be well aware of spare parts consumption (frequency of use) and quantity of inventory.
		3. Whether spare parts data are utilized for equipment management.
Instructor for Operator	Inspection	1. Can he teach (coach) pre-operation inspection and closing inspection?
	Operation	1. Can he read (understand) indications of meters and gauges properly?
		2. Can he work skillfully by using equipment?
		3. Can he teach (coach) how to operate equipment and how to work by using equipment?
	Safety Work	1. Does he fully understand safety work in the construction site?
		2. Can he teach (coach) how to operate equipment safely and how to work safely?
Instructor for Mechanic	Tools and Equipment	1. Can he manage to use (operate) mobile workshop?
		2. Can he use tools and workshop equipment skillfully?
	Safety Work	1. Does he fully understand safety work in the workshop?
		2. Can he teach (coach) safety work in the workshop?
	Repair Work	1. Does he fully understand structure and function of the components/devices equipped for the construction equipment?
		2. Does he have a skill to inspect and maintain/repair construction equipment?
		3. Can he teach how to inspect and maintain/repair construction equipment (theory & practice)?
Manager for Equipment Management	Workshop Management	1. Can he manage workshop and spare parts store operation?
	Equipment Management	1. Can he manage to control repair/maintenance of construction equipment?
		2. Can he carry out trouble shooting of construction equipment and give proper directions to mechanics?
		3. Does he understand procurement procedure of spare parts and availability of suppliers?
	Budget Management	1. Does he understand budget management (spare parts procurement and maintenance/repair of construction equipment)?

Source: Prepared by the Project Team

Based on the tasks determined according to the evaluation items shown in the table above, the Project Team supports the C/P to improve capability of trainees through OJT and workshops through daily road

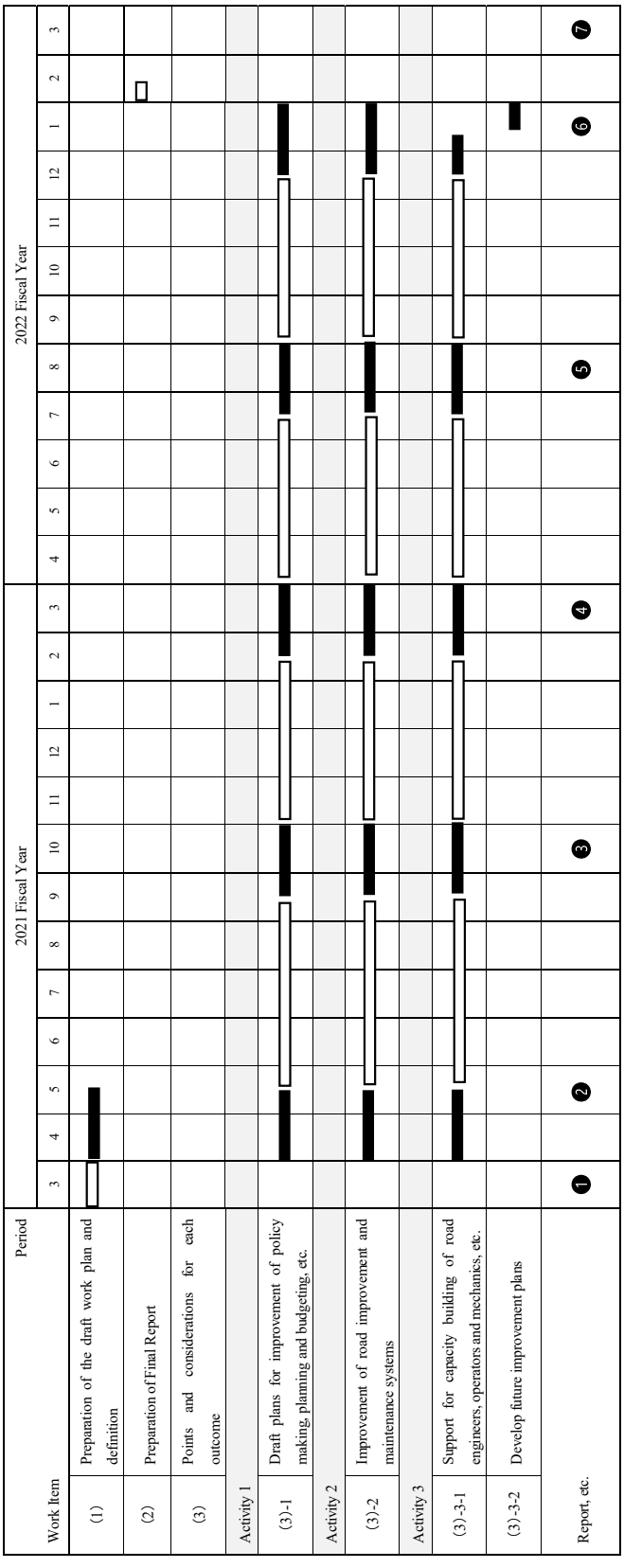
construction and maintenance services and equipment operation and maintenance services based on Figure 2-4 "Flowchart of Road Improvement, Maintenance and Equipment Operation".

In addition, a future improvement plans is formulated and proposed based on issues extracted through all activities in the Project.

3. Implementation Schedule

The implementation schedule of the Project is shown in Table 3-1.

Table 3-1 Implementation Schedule



4. Items Requested by the Project Team to the Uganda side

For the smooth implementation of the Project, items requested by the Project Team to the Uganda side are as follows:

1) To assign personnel, operators, etc. to receive technical trainings by the Project Team.
2) To provide the Project Team with available relevant data, information and materials as required.
3) To provide suitable office space and its facilities such as electricity, internet and furniture necessary for the project activities and operational expenses for utilities.
4) To share information in a timely manner in the event of organizational restructuring, personnel changes including those involved in the Project, or changes in the scope of MoWT's work/service, etc.
5) To share the most up-to-date trends in road-related projects by other donors in a timely manner.

END

Appendix 2. Attendance List

Attendance List

Organization and Name	Position
Ministry of Works and Transport	
Mr. Bageya Waiswa	Permanent Secretary
Eng. Samson Bagonza	Director of Engineering and Works/Engineer in Chief
Eng. Tony Bafirawala Kavuma	Chief Mechanical Engineer
Eng.Stephen Kiwanuka Kitonsa	Commissioner Roads and Bridges
Eng. Tibesigwa Timothy	Assistant commissioner Mechanical Services Operations
Eng.Winfred Naluyinda	Assistant commissioner Mechanical Services Inspection
Eng. Lumonya Jacob	Principal Executive Engineer
Eng. Allan Ndangizi	Principal Executive Engineer
Eng ARISHABA AGGREY	Senior Mechanical Engineer
Eng. Godfrey Magala	Senior Engineer /Urban 1Roads
Eng. Kisitu Timothy	Senior Engineer
Eng. Gerald Obalim	Deputy Force Account Manager, North
Mr. Keeya Francis	Workshop Manager in Bugembe
Eng.Karani Hanning	Workshop Manager in Gulu
Mr. Amugambe Eliab Tumwine	Workshop Manager in Mbarara
Ministry of Finance, Planning and Economic Development	
Mrs. Maris Wanyera	Ag. Director Debt and Cash Management
Nakawa Vocational Training Institute (NVTI)	
Mr. Muwanga Godfrey Fred	Principal
United Nations Industrial Development Organization (UNIDO)	
Mr. Stefan Windberger	Project Coordinator

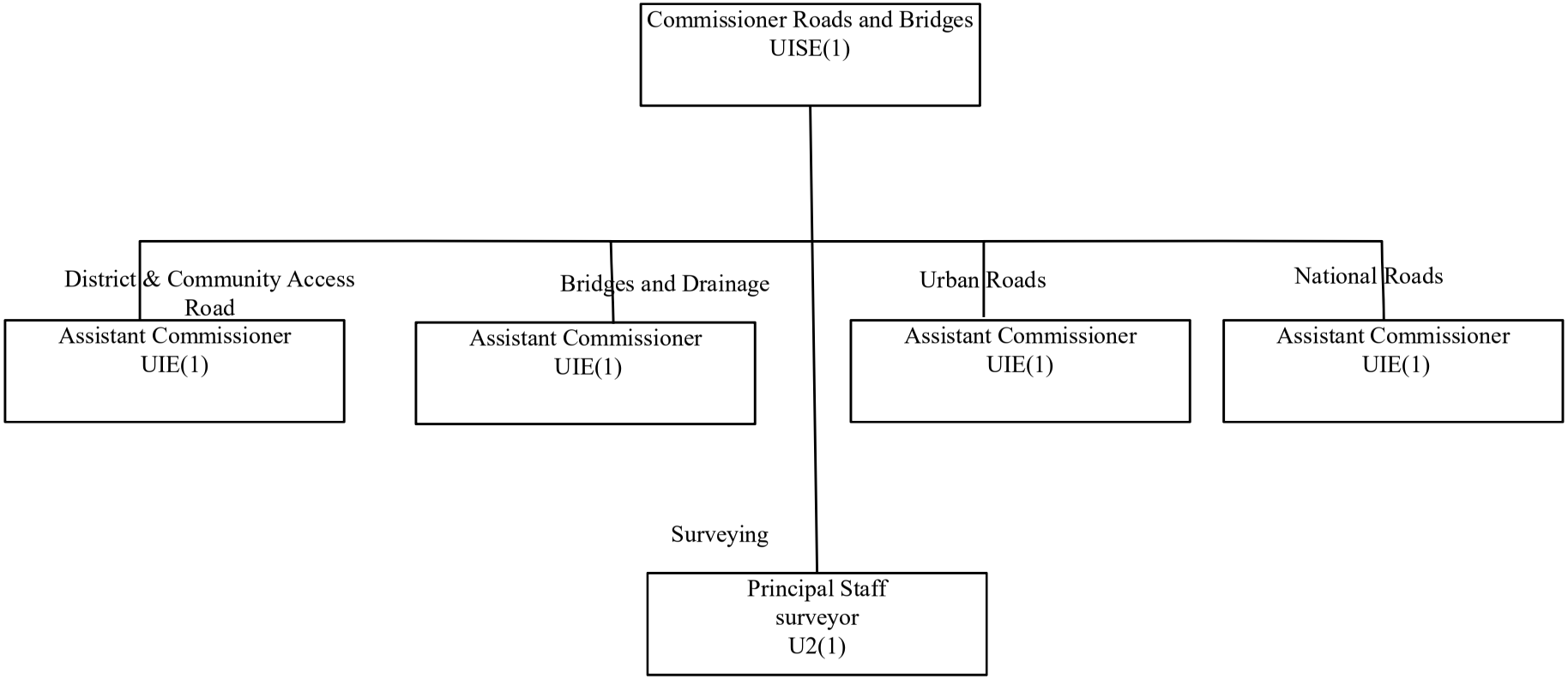
Japan International Cooperation Agency (JICA), Uganda Office

Mr. Yoichi Inoue	Chief Representative
Mr. Ichiro Fukuhara	Senior Representative
Mr. Koichiro Yamamoto	Representative
Ms. Atsumi Kani	Project Formulation Advisor
Mr. Makoto Terashima	Project Formulation Advisor
Ms. Meble Kasoma	Infrastructure Sector ODA and LOAN Operation

Appendix 3.

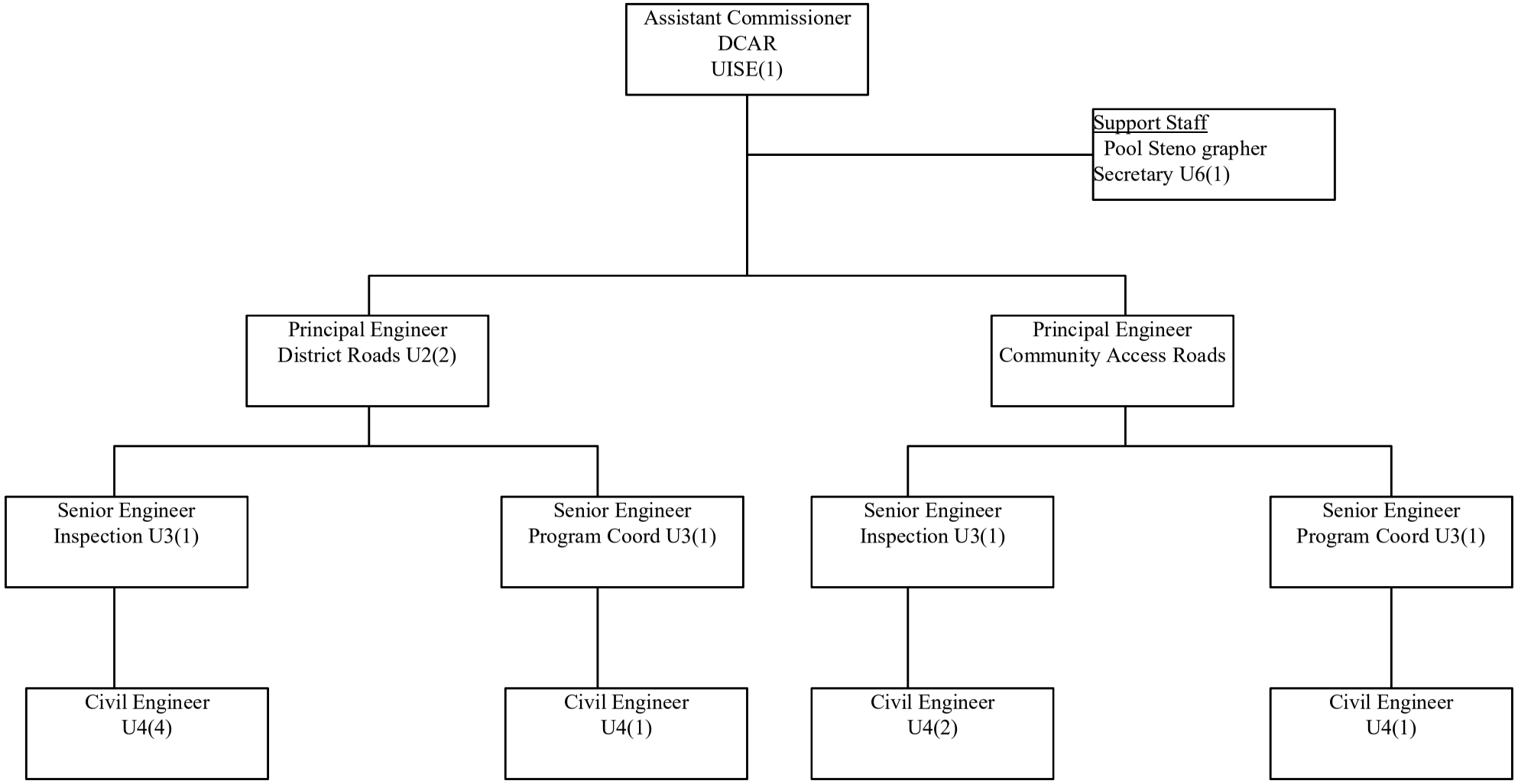
Organization Structure of the Department of Roads and Bridges, and the Department of Mechanical Engineering Services

ROADS AND BRIDGES DEPARTMNT

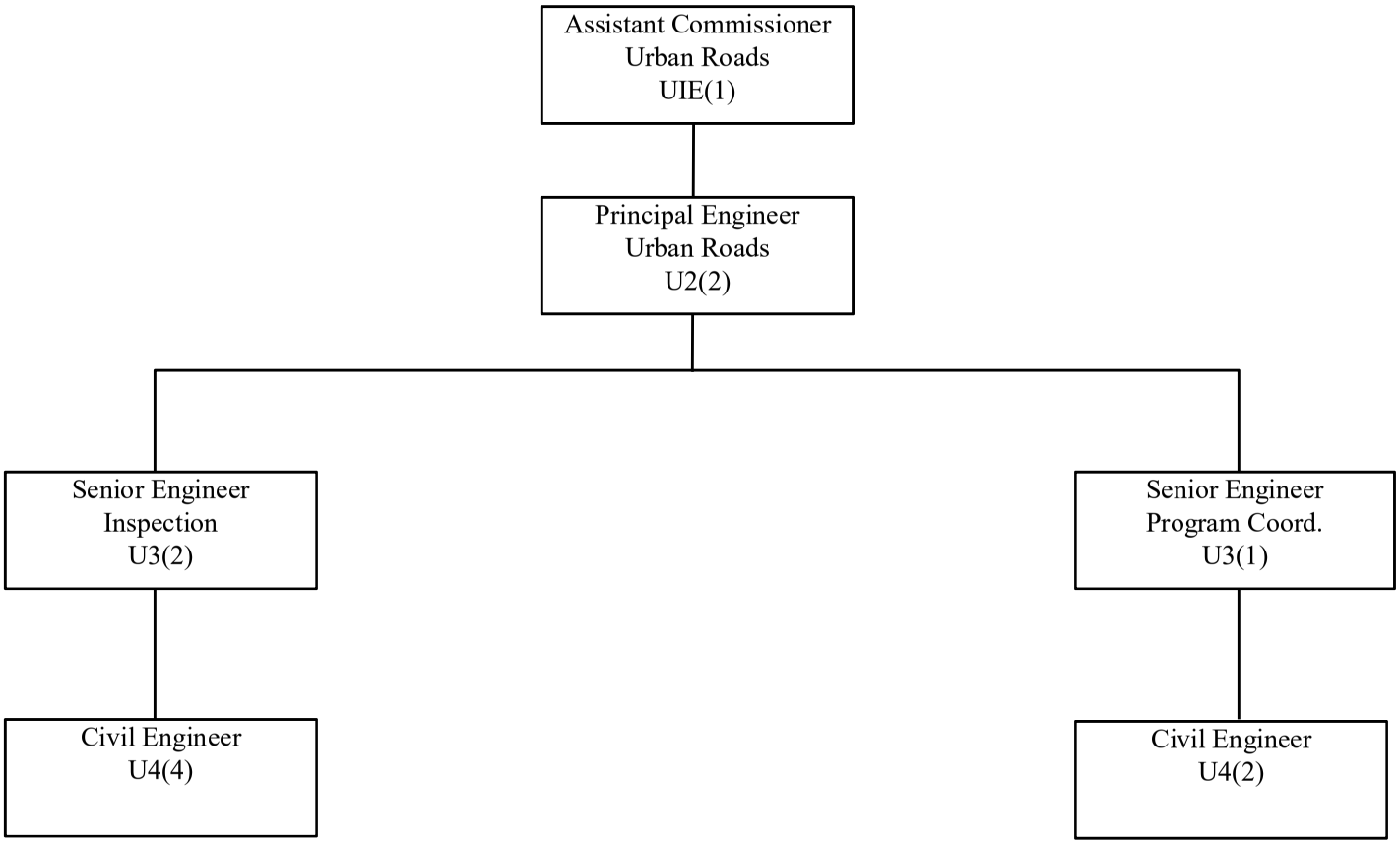


Administrative Support Staff
Personal Secretary U4(1)
Office Attendant U8(2)
Driver U8(7)

DISTRICT AND COMMUNITY ACCESS ROADS DIVISION

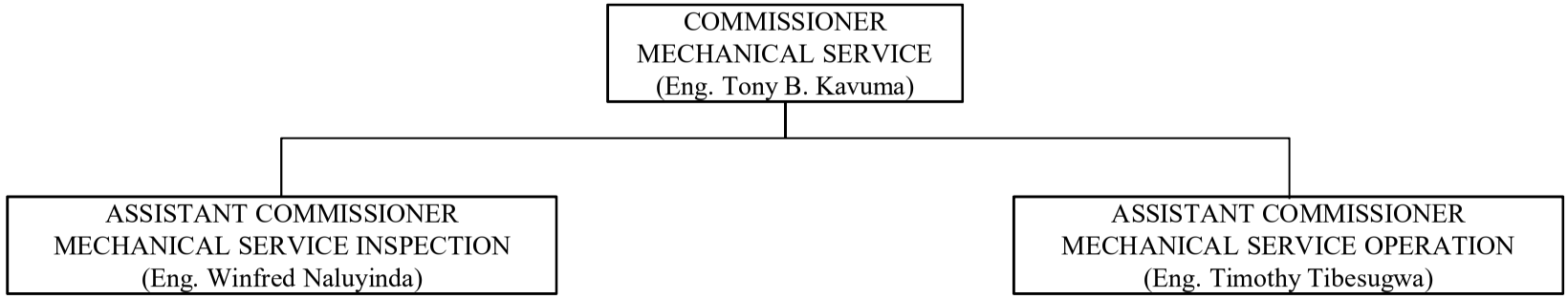


URBAN ROADS DIVISION



Support Staff
Pool Steno. grapher Secretary U6(1)

MECHANICAL SERVICE DEPARTMENT



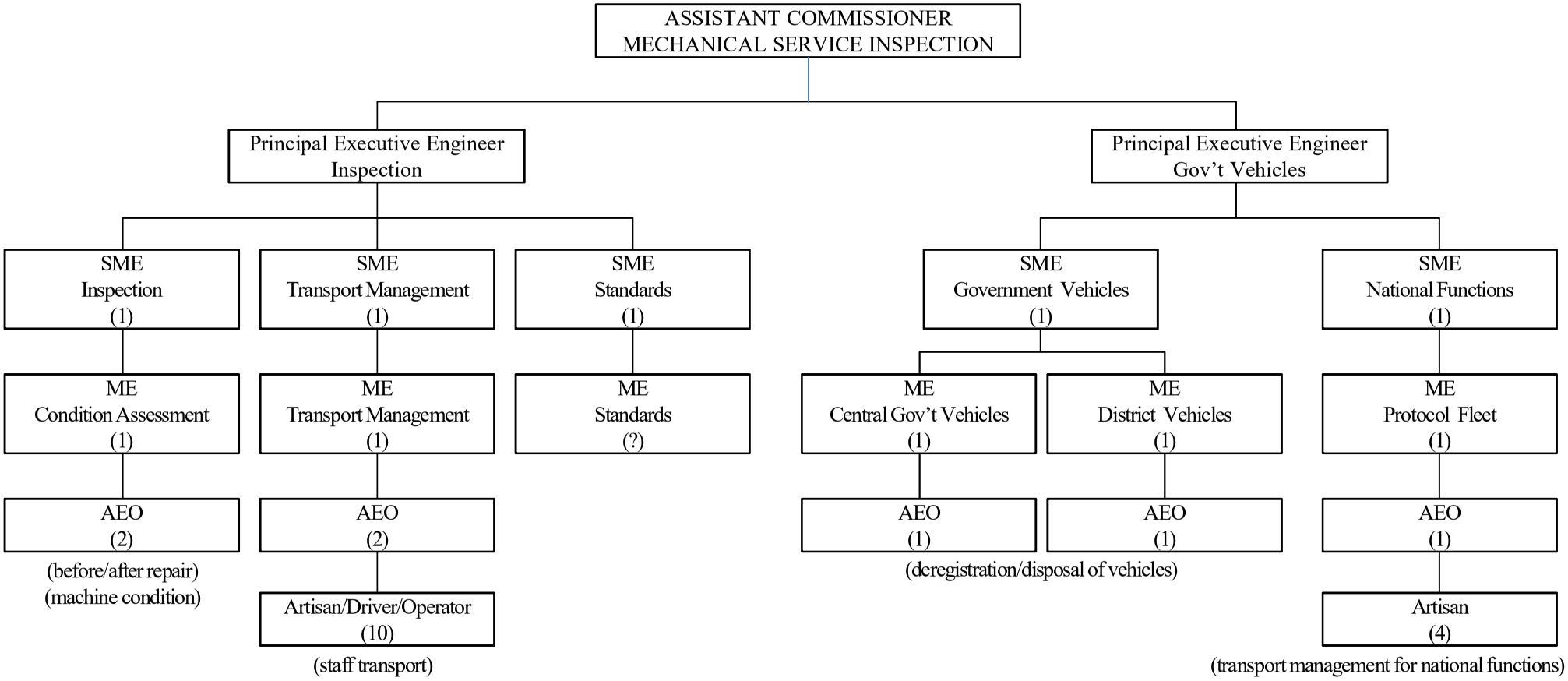
Manage equipment on inspection, procurement, deregistration (disposal), and manage transport for MoWT staff

- Inspect equipment conditions (before and after repair)
- Monitor equipment conditions
- Manage deregistration (disposal) of equipment
- Research for procuring equipment
- Prepare specifications for procuring equipment
- Manage transport for MoWT staff
- Manage transport for national functions

Manage registration, operation/utilization and maintenance of the equipment

- Manage operation of equipment
- Manage maintenance/repair of equipment
- Control utilization/use of equipment
- Monitor and inspect utilization/use of equipment
- Monitor and inspect operation conditions of equipment
- Monitor and inspect maintenance/repair of equipment
- Manage registration of equipment
- Control relocation of equipment

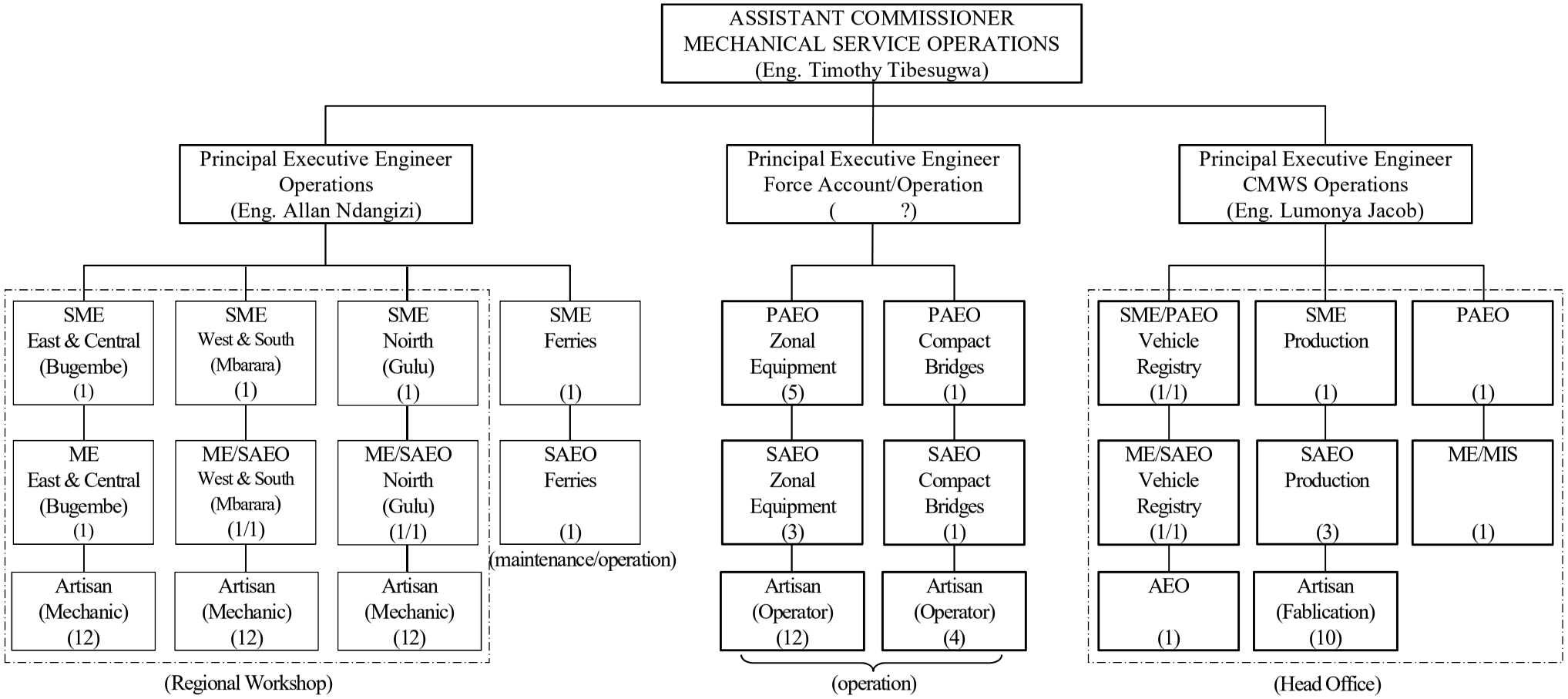
MECHANICAL SERVICE DEPARTMENT
INSPECTION DIVISION



Abbreviations

SME: Senior Mechanical Engineer
ME: Mechanical Engineer
PAEO: Principal Assistant Engineering Officer
SAEO: Senior Assistant Engineering Officer
AEO: Assistant Engineering Officer
MIS: Management of Information System

MECHANICAL SERVICE DEPARTMENT
OPERATIONS DIVISION



Abbreviations

SME: Senior Mechanical Engineer
ME: Mechanical Engineer
PAEO: Principal Assistant Engineering Officer
SAEO: Senior Assistant Engineering Officer
AEO: Assistant Engineering Officer
MIS: Management of Information System

Equipment under the control of Regional Offices

- Some types of equipment those are permanently stationed at the Regional Offices for general road maintenance works.
- Regional Offices manage use /utilization of those equipment independently.
- Minor maintenance and repair works such as periodic services are carried out by the Regional Offices (owners).
- Major repairs of these equipment are carried out by Regional Workshops by request from the Regional Offices.
- Outsourcing of repair works are managed by Regional Workshops.
- Regional Workshops manage/control procurement and storing operations for lubricants and spare parts for these equipment.

Zonal Equipment

- Some types of equipment those are temporally stationed/deployed at the regional offices for the force account projects.
- Mechanical Service Operation (MSO) division (Force Account Operation Section) manage/control these equipment.
- MSO Division (Force Account Operation Section) controls deployment and relocation of these equipment.
- Regional Workshops where the equipment stationed are responsible to manage maintenance of these equipment .
- Outsourcing of repair/maintenance works are controlled /managed by Regional Workshops.
- Regional Workshops manage/control procurement and storing operations for lubricants and spare parts for these equipment.

Appendix 4. Implementation Schedule (Plan/Actual)

Project Implementation Schedule (Plan/Actual)

Year/Month	March, 2022				April, 2022				May, 2022				June, 2022				July, 2022			
Quarter	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th
Disptch schedule	2nd field work →												← 3rd field work							
Items of Activity																				
Activity 1-1																				
1) Evaluate and analyze current systems for policy making, planning and budgeting																				
2) Interim meeting, review, etc.																				
3) Advice/Recommendation																				
Activity 2-1																				
1) Assess and analyze current systems for road construction and maintenance																				
Assess present construction execution plan, construction and maintenance, quality control, reporting																				
Assess annual planning of road construction/maintenance and actual records, road maintenance cycle, database of roads, badgeting																				
Assess implementation structure of Force Account																				
2) Advice/Recommendation																				
Activity 3-1																				
1) Implementation of TOT																				
Basic Course (Common) for Vehicle																				
Basic Course (Common) for Construction Equipment																				
Advanced Course for Heavy Equipment (KOMATSU)																				
Advanced Course for Vehicle (FUSO)																				
Advanced Course for Compaction Equipment (SAKAI)																				
Practical Training Course with OJT																				
2) Reporting													Reporting self-training						Reporting TOT by trainees	
Activity 3-2																				
1) Develop a future improvement plan																				
2) Advice/Recommendation																				
Submission of Report																				
1) Interim Report					▲															
2) Final Report																				

In the original plan, Team Leader's 3rd assignment was 1MM, but it was divided into 3rd 0.5MM and 4th 0.5MM.
Therefore, the assinment period of the 3rd field work was shortened from the original plan.

The schedule for this course was finalized according to the schedule of the advansed courses (compaction Equipment, heavy equipment) which were jointly

In the original plan, this course was scheduled to be implemented in the 5th field work, but due to schedule adjustments with local dealers and MoWT, the this course was implemented earlier.

Legend

: Plan
: Revised Plan, if any
: Actual

Remarks:

Activity 1, 2, 3-1 and 3-2 are corresponding to the one in Table 1-1 "Project Goals, Expected Outcomes and Outline of Activity".
- During absent from Uganda, JICA experts monitor MoWT's self-training activities related to "Activity 3-1" and provide advice as necessary.

Project Implementation Schedule (Plan/Actual)

Year/Month	August, 2022				September, 2022				October, 2022				November, 2022				December, 2022			
Quarter	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th
Disptch schedule						4th field work →														
Items of Activity																				
Activity 1-1																				
1) Evaluate and analyze current systems for policy making, planning and budgeting																				
2) Interim meeting, review, etc.																				
3) Advice/Recommendation																				
Activity 2-1																				
1) Assess and analyze current systems for road construction and maintenance													Actual period of the 4th Field Work							
Assess present construction execution plan, construction and maintenance, quality control, reporting																				
Assess annual planning of road construction/maintenance and actual records, road maintenance cycle, database of roads, badgeting																				
Assess implementation structure of Force Account																				
2) Advice/Recommendation																				
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Basic Course (Common) for Vehicle																				
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Advanced Course for Vehicle (FUSO)																				
Advanced Course for Compaction Equipment (SAKAI)																				
Practical Training Course with OJT																				
2) Reporting						Reporting self-training						Reporting TOT by trainees								
Activity 3-2																				
1) Develop a future improvement plan																				
2) Advice/Recommendation																				
Submission of Report																				
1) Interim Report	▲																			▲
2) Final Report																				

Legend

: Plan

: Revised Plan, if any

: Actual

Project Implementation Schedule (Plan/Actual)

Year/Month	January, 2023				February, 2023				March, 2023				April, 2023				May, 2023			
Quarter	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th
Disptch schedule	5th field work →																			
Items of Activity																				
Activity 1-1										Actual period of the 4th Field Work										
1) Evaluate and analyze current systems for policy making, planning and budgeting																				
2) Interim meeting, review, etc.																				
3) Advice/Recommendation																				
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2) Reporting	Reporting self-training					Reporting TOT by trainees														
Activity 3-2																				
1) Develop a future improvement plan																				
2) Advice/Recommendation																				
Submission of Report																				
1) Interim Report																			▲	
2) Final Report																				▲

Legend

: Plan

: Revised Plan, if any

: Actual

Appendix 5. Presentation Material for the Final Workshop

Technical Cooperation Project

CAPACITY DEVELOPMENT IN ROAD CONSTRUCTION AND MAINTENANCE

JAPAN INTERNATIONAL COOPERATION AGENCY
AND MINISTRY OF WORKS AND TRANSPORT
20th APRIL, 2023

Contents

1. Project Summary

2. Suggestions on Road Construction and Maintenance
   (1) Preventive Road Maintenance System
   (2) Action Plan in Road Maintenance Work for Its Cost Reduction and Proper Use of Road Maintenance Equipment

3. Suggestions on Proper Management and Maintenance of Road Equipment
   (1) Future Scope of Mechanical Services by MoWT Mechanical Workshop
   (2) Expected Annual Amount for Road Equipment Maintenance through Its Lifetime
   (3) Urgent Action suggested for Preventing a Breakdown of Heavy Equipment
   (4) Workshop Facility suggested for the Future in terms of Mechanical Services by MoWT

4. Expected Actions by MoWT

1. Project Summary

History of the Project

1. In 2017, the Government of Uganda procured 1,152 units of road construction and maintenance equipment from Japan at a cost of Approx. USD 150 million, and such equipment were distributed to 121 district and local governments, UNRA, KCCA, NEC and MoWT.
2. In 2021, JICA dispatched an expert team from Japan (hereinafter referred to as JICA Project Team) for capacity development for improvement of road construction and maintenance.
3. JICA Expert Team together with MoWT focal counterparts has developed expected outcomes leading the project goal.

Goals, Expected Outcomes and Outline of Activity

Project Goals	**MoWT personnel improve their capacity in the fields of road construction and maintenance.**
Expected Outcomes	**Outcomes 1:** Improvement measures for policy making, planning, and budgeting for road construction and maintenance of MoWT are proposed. **Outcomes 2**: A system for road construction and maintenance, including effective use of road construction equipment, of MoWT is improved in visible achievement of proper road construction/maintenance works for fair/good conditions. **Outcomes 3**: Capabilities of MoWT's road engineers, operators and mechanics through road construction/maintenance and use of equipment is strengthened.

1. Project Summary

Major Activities

1. Analyze of current capacity, implementation structure, and planning and budgeting system of MoWT on road construction and maintenance, and mechanical services.
2. Give a technical advice to improve road maintenance work more efficiently as well as road equipment management.
3. Carry out the Training of Trainer (TOT).
   8 members nominated from the Regional Mechanical Workshop (i.e. Kampala, Bugembe, Gulu, Mbarara) received a training from JICA expert and local dealer, so that they will be able to perform as a trainer to develop MoWT mechanics in the future.
4. Hold and attend several workshops among all concerned parties (i.e. Mechanical and Civil teams) under the Project to share a technical knowledge and discuss an action plan.

(1) Field Activities

Embankment work around swamp area

Drainage system to be improved

Inspection of equipment

Regional Workshop Map

(2) ToT Activities



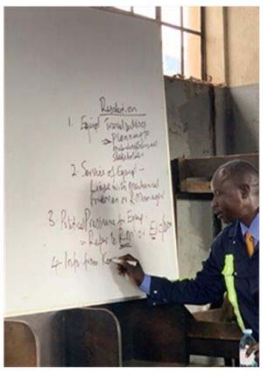



Training Program

Training Level	Training Outline
Basic Course	vehicle
	Construction equipment
Advanced Course	Heavy Equipment (KOMATSU)
	Vehicle (FUSO)
	Compaction Equipment (SAKAI)

Detailed training program was left as an outcome for future training by MoWT ToT member.

(3) Workshop

RESOLUTIONS OF THE TRAINING WORKSHOP WITH JICA EXPERTS, CIVIL ENGINEERS.TOT MECHANICS AND FORCE ACCOUNT MECHANICAL FOREMEN HELD ON 9/12/2022 AT CRMW KAMPALA.

S/N	CHALLENGES	RESOLUTIONS	RESPONSIBLE ENTITY /PERSONS
1	Wear of undercarriage	➢ Long Equipment travel should be avoided ➢ Plan for shifting of the equipment	➢ Plant operator ➢ Civil engineer and mechanical foremen
2	Use of equipment when it is overdue for service	➢ Equipment should be parked whenever it is due for service. ➢ Service should only be under taken by trained persons.	➢ Regional mechanical workshops ➢ Plant operators ➢ Mechanical foremen
3	Political pressure	➢ All political ➢ Request should be official.	➢ Permanent s secretary ➢ Engineer in chief ➢ Regional managers
4	Lack of komtrax information	➢ All managers and mechanical foremen should lease with TOT-mechanics and registered personnel	➢ TOT-Mechanics
5	Over consumption of fuel	➢ Follow up on fuel consumption by use of komtrax ➢ Operators should be encouraged to use Eco mode when in normal operating situation	➢ TOT mechanics and registered personnel.

What causes undercarriage wear on road construction equipment.	
Mechanical section	
Cause	Measures
Failure to carry out timely track chain adjustment.	Timely adjustments of undercarriage of equipment
Long travel hours of equipment from site to site.	Equipment to be transported on the low bed/ self-loader
Equipment operation on bad site terrains for long periods	Choice of right equipment

Created by civil and mechanical teams

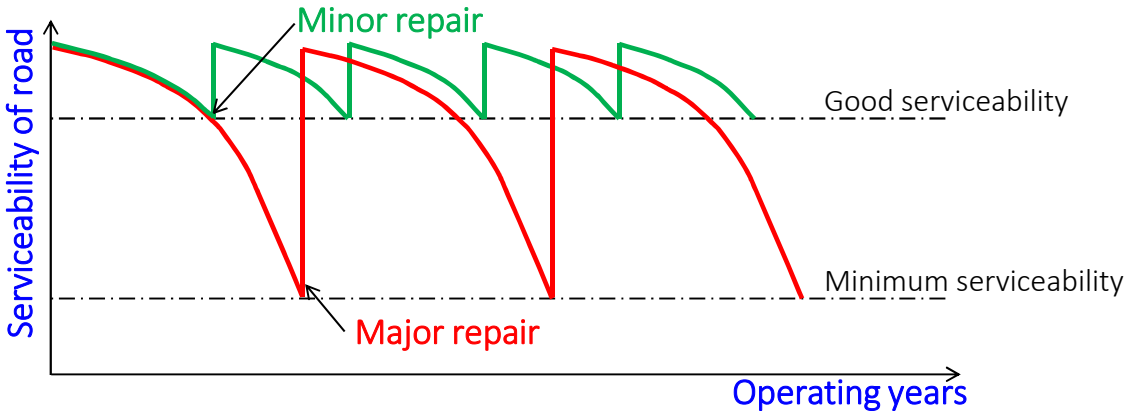
(4) Event

JICA expert team attended the 2nd ANNUAL INTEGRATED TRANSPORT INFRASTRUCTURE AND SERVICES (ITIS) PROGRAMME REVIEW WORKSHOP held on 8th December,2022 and made a presentation.

2. Suggestions on Road Construction and Maintenance

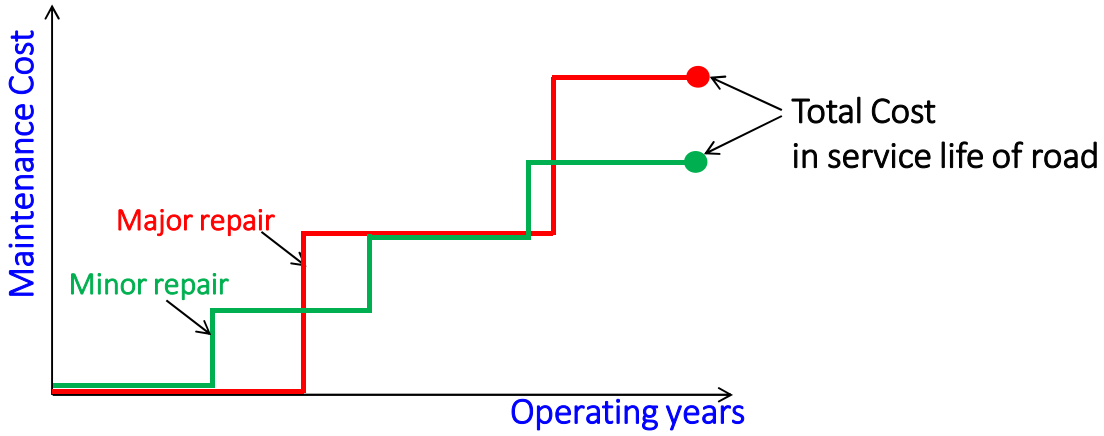
(1) Preventive Road Maintenance System

Frequency and scale of road maintenance related to total costs throughout its service life



Legend: Preventive Maintenance | Breakdown Maintenance

Total maintenance costs according to road maintenance methods



Total Cost: Preventive Maintenance < Breakdown Maintenance

When the Preventive Maintenance method is applied, cost reduction ratio is estimated approx. 20% according to a trial calculation as per a case example of district road in Uganda.

Road maintenance equipment according to its scale

Breakdown Maintenance

Motor Grader

Large-scale Compactor

Asphalt Finisher

Preventive Maintenance

Asphalt Cutter

Asphalt Burner

Bitumen Sprayer

Small-scale Compactor

Transporter for maintenance equipment

Breakdown Maintenance | Preventive Maintenance

Low-bed Semi-trailer,
Self Loading Truck, etc.

Cab-back Crane Cargo Truck

Small-scale equipment is able to be transported to sites at one time by Cab-back Crane Cargo Truck, and mobilization costs are reduced.

Popular method of small-scale maintenance

Damaged area

Remove damaged area

Clean up the surface

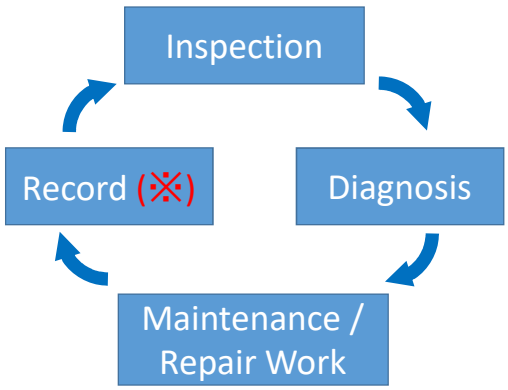
Spray bitumen (e.g. Tack coat)

Pave with mixed asphalt material

Compaction

Future perspective of road maintenance by MoWT

- MoWT carries out the preventive road maintenance in a circulation of an inspection, diagnosis, maintenance/repair works and record.
- By the above method, MoWT is able to optimize costs to maintain roads using its construction equipment in good conditions.



※ Rural Road Database System, which was developed in MoWT by JICA's past technical cooperation, can help accumulating road maintenance records efficiently so that MoWT will estimate a budget for periodic road maintenance in a timely manner. .

(2) Action Plan in Road Maintenance Work for Its Cost Reduction and Proper Use of Road Maintenance Equipment

Issues to be resolved

- Remarkable gap between busy period and non-busy period in road maintenance work
- Over burden on equipment due to a long-distance travel of heavy equipment (e.g. excavators, bulldozers, rollers) that are not suitable for self-propulsion
- Inefficient fuel consumption due to long-distance travel of heavy equipment

Typical operation records of heavy equipment

	Date	Working Status (Monthly)	Working Days	Working Hours	Actual Working Hrs.	ATT	Travel	Daily Avg.	Amount of Fuel Consumed
1st and 2nd quarter in the budget year 2022/23	12/2022		-	-	-	-	-	-	197L
	11/2022		6 Days	25H	21.3H	0H	4.7H	4.1H	320L
	10/2022		3 Days	11H	7.9H	0H	3.1H	3.6H	102L
	09/2022		7 Days	19H	15.1H	0H	4H	2.7H	253.2L
	08/2022		0 Days	0H	0.1H	0H	0.1H	-	2.5L
	07/2022		7 Days	12H	9.3H	0H	2H	1.7H	71.1L
3rd and 4thc quarter in the budget year 2021/22	06/2022		22 Days	103H	81.4H	0H	11.1H	4.6H	1370.8L
	05/2022		14 Days	57H	50.3H	0H	6.8H	4H	838.5L
	04/2022		22 Days	121H	106.1H	0H	15.1H	5.5H	1943.9L
	03/2022		8 Days	27H	22.6H	0H	4.4H	3.3H	399.8L
	02/2022		12 Days	23H	18.7H	0H	5.1H	1.9H	210L
	01/2022		16 Days	57H	44H	0H	10.5H	3.5H	690.3L

Source: Collected data from the GPS tracking system of excavator (PC220-8M0, 100865)

Challenges, Resolutions and Responsible Entity/Persons in Road Maintenance Using Equipment

S/N	CHALLENGES	RESOLUTIONS	RESPONSIBLE ENTITY /PERSONS
1	Wear of undercarriage	➢ **Long Equipment travel (※)** should be avoided ➢ Plan for the shifting of the equipment	➢ Plant operator ➢ Civil engineer and mechanical foremen
2	Use of equipment when it is overdue for service	➢ Equipment should be parked whenever it is due for service. ➢ Service should only be under taken by trained persons.	➢ Regional mechanical workshops ➢ Plant operators ➢ Mechanical foremen
3	Political pressure	➢ All political request should be official.	➢ Permanent secretary ➢ Engineer in chief ➢ Regional managers
4	Lack of komtrax information	➢ All managers and mechanical foremen should liaise with TOT-mechanics and registered personnel	➢ TOT-Mechanics
5	Over consumption of fuel	➢ Follow up on fuel consumption by use of komtrax ➢ Operators should be encouraged to use Eco mode when in normal operating situation	➢ TOT mechanics and registered personnel.

Source: Prepared by the participants of the joint workshop between civil and mechanical teams

※ For example, the manufacturer of excavator recommends self-propulsion within only 5 km per movement.

3. Suggestions on Proper Management and Maintenance of Road Equipment

(1) Future Scope of Mechanical Services by MoWT Mechanical Workshop

Category of Maintenance Works	To be carried out by:
1. Routine service and minor repairs	MoWT Regional Mechanical Workshops
2. Major /Specialized repairs and overhauls	MoWT contracted franchised dealers/service providers

Scope of Mechanical Services to be undertaken by MoWT and Private Sector

Service level	Type of equipment servicing and repair	Main work items	Demarcation		
			MoWT		Manufacturer / Local Dealer
			Central Workshop	Regional Workshops	
1 Light	Periodical Maintenance	Change lubricants, lubrication	○	○	
2	Inspection and adjustment	Adjusting brake, adjusting clutch etc.	○	○	
3	Minor repair and maintenance	Replacement of consumable parts	○	○	
4	Overhaul of the main component	Engine, clutch, transmission, hydraulic component etc. (mechanical component/device)	△ Note 1	△ Note 1	○
		Undercarriage of construction equipment (part replacement) Note 2	○	○	○
5 Heavy	Trouble shooting and repair of electronic component /device	Electric/electronic/hydraulic control system, for engine, power train and hydraulic component etc.			○
6	Major overhaul and repair, and modifications	Major overhaul/repair of equipment and modifications			○

Note 1: JICA expert understands that MoWT has experience and achievements for small vehicles. Therefore, a repairing work of small vehicles are classified as MoWT's direct operation..

Note 2: Replacement of parts around the undercarriage of construction equipment is going to be carried out by MoWT directly or by utilizing private service providers, depending on the content of maintenance and MoWT's budgetary conditions.

Source: Prepared by MoWT and the Project Team

(2) Expected Annual Amount for Road Equipment Maintenance through Its Lifetime

	Name of Equipment	Estimated Value of Equipment (JPY)(CIP) (a)	Machine's life span (years) (b)	Mainte. cost Rate (in life span) (%) (c)	Total maintenance cost (JPY/unit)	Av. mainte. cost/year (JPY/unit) (d) = Value of equipment x (c/100)÷b	Mainte. cost for remained years (JPY/unit)	Mainte. cost per year for remined years (JPY per year/unit)	Number of equipment (unit) (e)	Total mainte. cost per year for remained years (JPY)
1	Morter Grader GD663-2	19,000,000	10	55	10,450,000	1,045,000	6,270,000	1,254,000	143	179,322,000
2	Wheel Loader WA250-5	18,000,000	10	40	7,200,000	720,000	4,320,000	864,000	122	105,408,000
3	Wheel Loader WA430-5	32,000,000	10	30	9,600,000	960,000	5,760,000	1,152,000	13	14,976,000
4	Excavator PC220-8 Standard	25,000,000	10	55	13,750,000	1,375,000	8,250,000	1,650,000	21	34,650,000
5	Excavator PC220-8 Long-Boom	27,000,000	10	55	14,850,000	1,485,000	8,910,000	1,782,000	0	0
6	Bulldozer D65EX-16	28,000,000	10	55	15,400,000	1,540,000	9,240,000	1,848,000	25	46,200,000
7	Wheel Backhoe Loader	13,400,000	10	50	6,700,000	670,000	4,020,000	804,000	31	24,924,000
8	Vibratory Roller 10ton SV520D	8,400,000	10	40	3,360,000	336,000	2,016,000	403,200	141	56,851,200
9	Pneumatic Tyre roller TS200	5,720,000	10	45	2,574,000	257,400	1,544,400	308,880	4	1,235,520
10	Pedestrain Roller 0.8ton HV80	1,880,000	10	40	752,000	75,200	451,200	90,240	18	1,624,320
11	Plate compactors 4.3Hp PC63	250,000	7	40	100,000	14,286	60,000	30,000	20	600,000
12	Tampers/Rammers RS55E	321,000	7	30	96,300	13,757	57,780	28,890	18	520,020
13	Dump Truck 8ton	12,000,000	10	30	3,600,000	360,000	2,160,000	432,000	276	119,232,000
14	Dump Trucks with chip spreader	13,500,000	10	30	4,050,000	405,000	2,430,000	486,000	7	3,402,000
15	Cargo Truck 8ton	10,414,992	10	45	4,686,746	468,675	2,812,048	562,410	9	5,061,686
16	Water bowser 8,000L	10,966,217	10	45	4,934,798	493,480	2,960,879	592,176	138	81,720,249
17	Low bed tructor pay load 30ton	36,000,000	10	35	12,600,000	1,260,000	7,560,000	1,512,000	9	13,608,000
18	Self-loading truck pay load 15ton	25,000,000	10	45	11,250,000	1,125,000	6,750,000	1,350,000	21	28,350,000
19	Mobile Workshop	18,000,000	10	50	9,000,000	900,000	5,400,000	1,080,000	5	5,400,000
20	Mobile crane 35ton	43,000,000	10	25	10,750,000	1,075,000	6,450,000	1,290,000	1	1,290,000
21	Bitumen Distributor	19,936,380	10	30	5,980,914	598,091	3,588,548	717,710	4	2,870,839
22	Bulldozer D85EX-15R	32,000,000	10	40	12,800,000	1,280,000	7,680,000	1,536,000	0	0
23	Tandem roller CR271 1.44ton	2,200,000	7	30	660,000	94,286	396,000	198,000	4	792,000
24	Vibratory Roller 15ton SV700	20,020,000	7	35	7,007,000	1,001,000	4,204,200	2,102,100	0	0
25	Vibratory Roller 18ton SV700	22,000,000	7	45	9,900,000	1,414,286	5,940,000	2,970,000	0	0
26	Double drum Vibratory Tandem Roller	13,090,000	7	50	6,545,000	935,000	3,927,000	1,963,500	1	1,963,500
27	Tandem roller SW800 10.4ton	13,300,000	7	25	3,325,000	475,000	1,995,000	997,500	0	0
28	Vibrator combinmed roller TW504	5,500,000	7	30	1,650,000	235,714	990,000	495,000	1	495,000
Total in JPY								**28,499,605**		**730,496,334**
Total in USD								**219,228**		**5,619,203**

Exchange rate: USD 1 = JPY 130
Source: JICA Project Team

Total maintenance cost per year till the end of service life:
USD 5.6 million per year

(3) Urgent Action suggested for Preventing a Breakdown of Heavy Equipment

Urgent action is needed for Repair of the Undercarriage of Crawler Equipment.

- The operating hours has reached 3,000 to 5,000 hours since the GoU procured equipment in 2017 under Japanese loan program, and the cost for repairs is increasing.
- In particular, undercarriage parts of a Bulldozer and Excavator have been rapidly deteriorated, and most of such equipment will soon breakdown unless undercarriage's spare parts will be urgently renewed with new parts or will be repaired by a dedicated equipment for rebuilding of undercarriage.

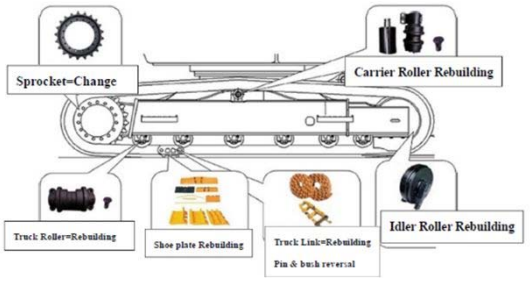
Bulldozer

Excavator

MoWT's Road Equipment with undercarriage of the track running device

No	Type of Machine	Model		Quantity
4	* Excavator	Komatsu PC220-8 Standard	173Hp	30
5	* Excavator	Komatsu PC220-8 Long Boom	173Hp	3
6	* Bulldozer	Komatsu D65EX-15	207Hp	31
22	* Bulldozer	Komatsu D85EX-15R		2
			Total	**66**

Urgent needs of maintenance



Renewable parts of an undercarriage system

Comparison of Maintenance Cost

Estimated cost for renew of undercarriage with KOMTSU genuine spare parts

UNIT: UGX

No	Type of Machine	Model	Unit Price	Qty	Price
1	Excavator	Komatsu PC220-8 Standard	146,500,000	30	**4,395,000,000**
2	Excavator	Komatsu PC220-8 Long Boom	146,500,000	3	**439,500,000**
3	Bulldozer	Komatsu D65EX-15	182,500,000	31	**5,657,500,000**
4	Bulldozer	Komatsu D85EX-15R	219,000,000	2	**438,000,000**
					10,930,000,000

Note: Above amount is only for procurement of spare parts, but not including labor costs.

Approx. USD 2,920,000

Estimated cost for repair of undercarriage if MoWT has dedicated rebuilding equipment

UNIT: UGX

No	Type of Machine	Model	Unit Price	Qty	Price
1	Excavator	Komatsu PC220-8 Standard	116,830,000	30	3,504,900,000
2	Excavator	Komatsu PC220-8 Long Boom	116,830,000	3	350,490,000
3	Bulldozer	Komatsu D65EX-15	146,777,000	31	4,550,087,000
4	Bulldozer	Komatsu D85EX-15R	175,200,000	2	350,4000,000
					8,755,877,000

Note: Above amount includes labor costs based on direct operation by MoWT.

Approx. USD 2,340,000

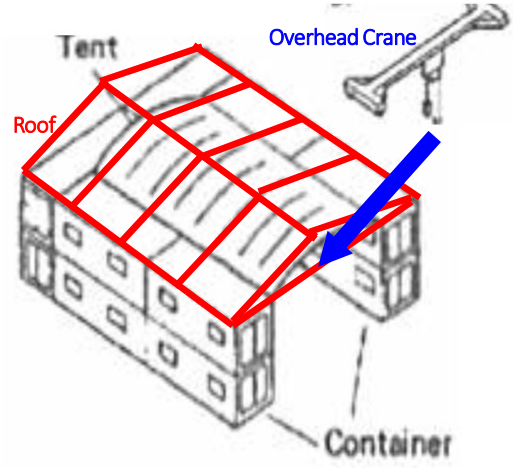
Result of Comparison

- The initial cost for undercarriage rebuilding equipment is estimated approx. UGX6.4 billion (USD1,700,000) if MoWT will procure it.
- After procurement, MoWT can reduce UGX2.2 billion (USD580,000) of undercarriage repairing costs per single round of its repair for all 66 units of excavators and bulldozers.
- Moreover, the undercarriage rebuilding equipment can be used even for other manufacture's model, so that cost reduction will be continuously achieved beyond above amount.

(4) Workshop Facility suggested for the Future in terms of Mechanical Services by MoWT

- In terms of current facility and equipment in the regional workshops, MoWT will soon need to upgrade all workshops for proper and efficient in-house maintenance operation.
- In particular, both regional workshop in Gulu and Mbarara needs to be upgraded due to lack of facility and its deterioration.
- For the above, simple mechanical workshop equipped with only essential facilities, equipment, office room, etc., which can be developed at low cost, is recommended in terms of their function for mechanical services.

(4) Workshop Facility suggested for the Future in terms of Mechanical Services by MoWT



Example of Simple Mechanical Workshop comprised of containers, essential facilities, etc.

Initial cost of a simple mechanical workshop: USD 2 million or less per each place

4. Expected Actions by MoWT

1. Proper preventive maintenance while optimizing the maintenance cost within limited budget.
2. Adequate budget for preventive and corrective maintenance for road equipment.
3. Proper planning and operation of road maintenance in collaboration of civil and mechanical teams, based on the Action Plan.
4. Continuous training led by ToT member to develop MoWT mechanics at respective Regional Mechanical Workshops.
5. Regular report on above achievement to JICA Uganda Office.

THANK YOU
&
GOD BLESS YOU

Appendix 6. Recommendations

ADVISOR FOR CAPACITY DEVELOPMENT IN ROAD CONSTRUCTION AND MAINTENANCE IN THE REPUBLIC OF UGANDA

Recommendations

June 2023

YACHIYO ENGINEERING CO., LTD.

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1. Example of Pavement Design
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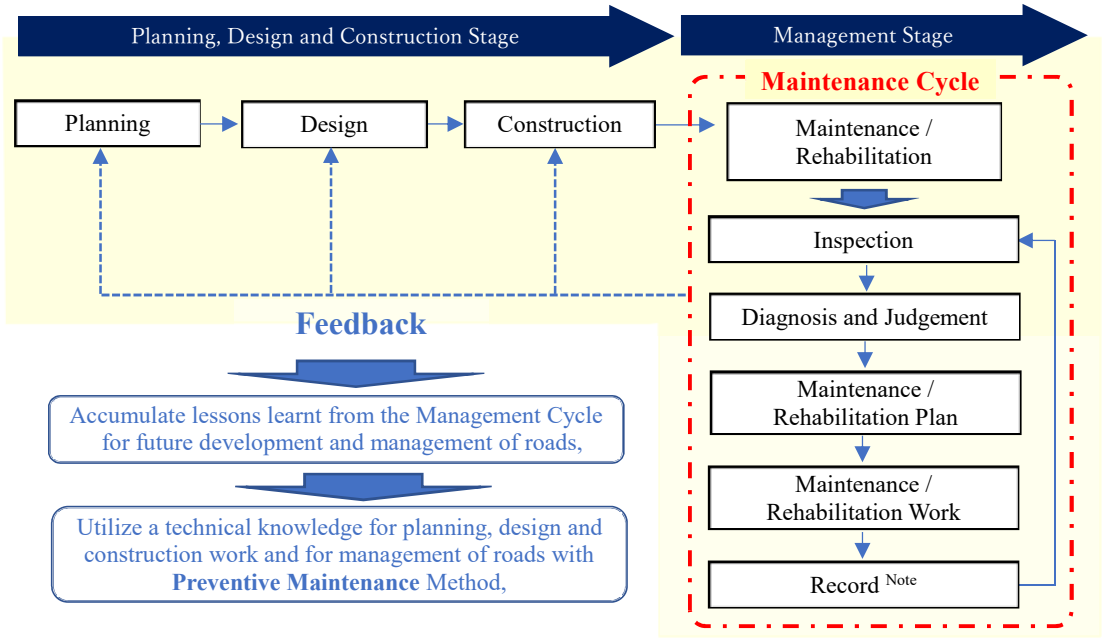
Chapter 1. Recommendations on Road Management

1. Improvement of Policy Making, Planning and Budgeting for Road Maintenance

(1) Facilitating the Asset Management and Preventive Road Maintenance System

In order for MoWT to improve efficiency of road maintenance and rehabilitation works and manage roads in proper manner for a long term, it is crucial to optimize a series of Asset Management Cycle: planning, design, construction, maintenance and updating.

Figure 1-1 shows a work flow of the Asset Management to contribute to proper road management system.



Note: Database system for district and urban roads is effectively utilized in records of maintenance / rehabilitation work.
Source: JICA Project Team

Figure 1-1 Work Flow in Asset Management

In a road management, there are many cases where roads have initial defects at the time of completion due to various factors. In that case, in addition to maintaining roads as per the maintenance cycle described in Figure 1-1 above, it is important that MoWT feedbacks what learnt through operation in the maintenance cycle to the previous stages, namely planning, design and construction, and improve the quality of the previous stage, for future practices as well as capacity improvement of asset management system.

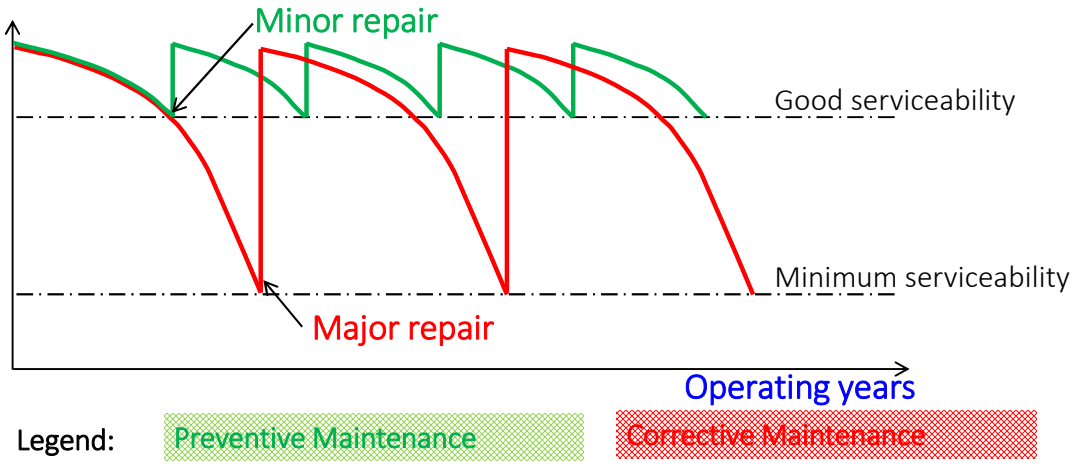
In implementing the maintenance cycle at the management stage shown in Figure 1-1, it is recommended to actively utilize the Database System for District and Urban Roads developed in the JICA's past project.

(2) Preventive Maintenance System

MoWT has been performing post-maintenance called as a Corrective Maintenance System, and have been forced to carry out costly large-scale road rehabilitation works. After all, rehabilitation costs tend to increase

as a result of being left uncontrolled for many years without being able to respond within a limited road maintenance budget. In order to improve current situation, it is necessary to shift the maintenance method to a Preventive Maintenance System. For introduction of the Preventive Maintenance, it is important to record the presence and extent of road damage based on periodic and non-periodic inspections of roads under the jurisdiction, prioritize necessity and urgency of maintenance, and finally reflect it in application of annual budget in order to realize a systematic operation and maintenance of roads.

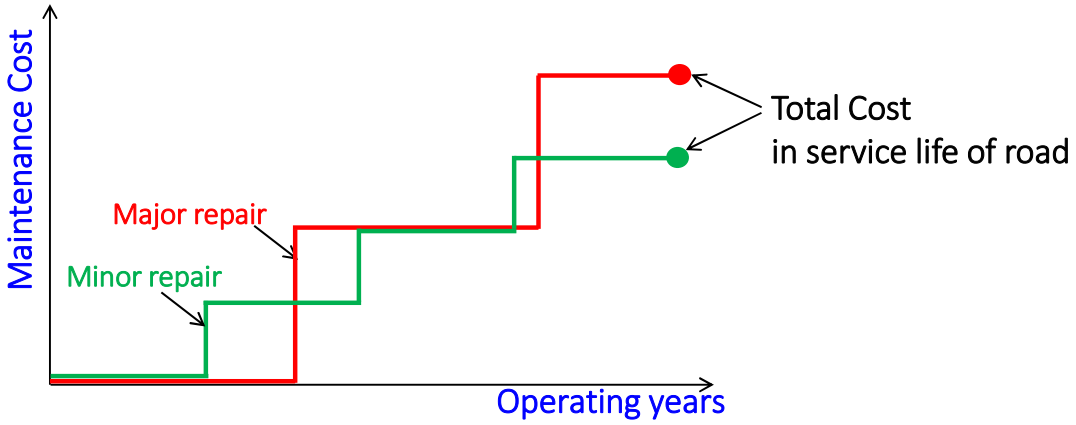
Figure 1-2 shows a conceptual diagram comparing the Corrective Maintenance and the Preventive Maintenance in the life cycle of road.



Source: JICA Project Team

Figure1-2 Comparison of Maintenance Systems

The typical cost comparison for each maintenance system, namely the Corrective Maintenance and the Preventive Maintenance, shown in the above Figure1-2 are as shown in Figure 1-3.



Source: JICA Project Team

Figure1-3 Comparison of Maintenance Cost by Maintenance Systems

Although the figure above is a conceptual diagram, it is possible to reduce the cost over the service life of roads by performing small-scale maintenance work in an appropriate cycle.

Above-mentioned small-scale maintenance includes repairing small potholes and ruts on road surfaces, repairing cracks in asphalt pavement, cleaning drainage structures and gutters, etc. as show in Figure 1-4 and Figure1-5. These works can be carried out with relatively small-scale road maintenance equipment as shown in Figure 6.

Source: JICA Project Team

Figure1-4 Road Maintenance with Filling Port Hole

Source: JICA Project Team

Figure1-5 Road Maintenance with Filling Crack

Equipment for Corrective Maintenance	Equipment for Preventive Maintenance
 Motor Grader  Large-scale Compactor  Asphalt Finisher  Low-bed Trailer, Self-loading Truck, etc.	 Asphalt Cutter  Asphalt Burner  Asphalt Sprayer  Small-scale Compactor  Cab-back Crane Cargo Truck

Source: JICA Project Team

Figure1-6 Road Maintenance Equipment by Maintenance Systems

While the Corrective Maintenance requires the large-scale transportation vehicle to mobilize large-scale equipment with several round trips to a site depending on the number of equipment to be used, the Preventive Maintenance requires the Cab-back Crane Cargo Truck to mobilize small-scale equipment which are able to be transported to a site at one time.

The Preventive Maintenance, therefore, contribute to reduction of mobilization costs including a fuel cost.

Next, a model section is selected from among the roads under the jurisdiction of the MoWT, and road maintenance costs are compared by simulating the Corrective Maintenance and the Preventive Maintenance. Table 1-1 is a trial calculation of the total road maintenance cost over a long period of about 10 years, using the LAPANA-ONYALA ROAD (6.7km) in Kitgum District in the northern region as a model section. According to the trial calculation, it is possible to reduce the cost of Preventive Maintenance to 81% of that of Corrective Maintenance. This trial calculation is only an example of roads in Uganda, but by implementing

periodic and planned minor maintenance and repair woks, it is possible to reduce total costs compared to the current Corrective Maintenance. In addition, the cost reduction effect is considered to be greater in remote areas where it is difficult to access with heavy equipment such as a bulldozer, excavator, large-scale compactor, etc.

Table1-1 Comparison of Road Maintenance Cost by Maintenance System

Unit: Ugx

Items	Corrective Maintenance		Preventive Maintenance				
	Major Rehabilitation		Minor Mainitenance		Minor Rehabilitation		Total (b)
	Cost per work	Total (a)	Cost per work	Sub-total	Cost per work	Sub-total	
Bush Clearing and Road Formation	18,975,000	37,950,000	5,692,500	17,077,500	11,385,000	11,385,000	28,462,500
Road Gravelling	74,175,000	148,350,000	22,252,500	66,757,500	44,505,000	44,505,000	111,262,500
Excavation for Road Drainage	7,705,000	15,410,000	2,311,500	6,934,500	4,623,000	4,623,000	11,557,500
Plant Maintenance	14,999,250	29,998,500	2,999,850	8,999,550	8,999,550	8,999,550	17,999,100
Construction Materials	105,418,000	210,836,000	31,625,400	94,876,200	63,250,800	63,250,800	158,127,000
Labour/Staff Allowances.	42,680,000	85,360,000	25,608,000	76,824,000	25,608,000	25,608,000	102,432,000
Administrative Expenses	21,700,000	43,400,000	6,510,000	19,530,000	13,020,000	13,020,000	32,550,000
Quality Control	5,000,000	10,000,000	1,500,000	4,500,000	3,000,000	3,000,000	7,500,000
Total	290,652,250	581,304,500	98,499,750	295,499,250	174,391,350	174,391,350	469,890,600
						Cost Reduction Ratio (b/a)	81%

Source: Calculated by JICA Project Team based on cost estimation materials of MoWT

(3) Criteria to Determine Frequency and Timing for Maintenance according to Road Classification and Service Level

It is recommended to classify road surface conditions that require maintenance according to road classifications and the characteristics of passing vehicles, and to implement the Preventive Maintenance, accordingly. Table 1-2 shows the major type of traffic vehicles assumed according to the road classification, and organize the service level that can be stably passed for traffic vehicles with specific values of road surface conditions.

Table 1-2 Condition of Road Surface Requiring Maintenance

Road Classification / Pavement Structure	Major Type of Traffic	Recommended Road Surface Conditions to Ensure Service Levels for Stable Traffic	Estimated Frequency
Urban City Road / Asphalt Pavement	Normal passenger car, 4WD, Pick-up Truck, Heavy Vehicle, Agricultural Vehicle and Machine	➢ Keep the maximum depth of potholes and ruts below 4-5cm considering the height of normal passenger cars ➢ Since normal passenger cars (approximately 3.5 to 5m in length) pass, the number of potholes should be kept at 25 or less per 100m of road length (=100m in length/4m in length). Damage exceeding this makes it difficult for passenger cars to avoid potholes and hinders safe passage. ➢ Cracks are less than 30-35% of pavement area.	Every 3 to 5 years. However, priority will be given to road surface inspection results after the rainy season.
District and Community Access Roads / Gravel or Earth Road	4WD, Pick-up Truck, Heavy Vehicle, Agricultural Vehicle and Machine	➢ Keep the depth of potholes and ruts to about 15 cm or less considering the vehicle height of the smallest passing vehicle (small truck). ➢ Keep the number of potholes below 20 per 100m road length (= 100m length/5m vehicle length), depending on the minimum number of passing vehicles (small trucks). Damage that exceeds this makes it difficult for passing vehicles to avoid potholes and hinders safe passage.	Every 3 to 5 years. However, priority will be given to road surface inspection results after the rainy season.

Note
Light Truck (2～3t) : 4.7m or less in length
Middle Truck (4t) : 12m or less in length
Heavy Truck (10t and more) : 12m or less in length
Source: JICA Project Team

As a measure that a road administrator can quantitatively and objectively determine the timing and priority of maintenance and rehabilitation of roads under their jurisdiction under the limited road maintenance budget for every fiscal year, a method of evaluating priority by adding points based on the classification and characteristics of the road and the degree of deterioration is recommended.

This method is to assign points to a candidate road for maintenance based on the evaluation items shown in Table 1-3, and determines the priority and urgency of maintenance and rehabilitation based on the total score for reflecting the result to road maintenance and rehabilitation plan of the coming or later fiscal year.

Table 1-3 Priority Evaluation Items and Point Allocation for District and Community Access Roads

No.	Category	Evaluation Items	Point Allocation
1	Characteristic of Road	Functional Classification	／10
		AADT (Annual average daily traffic), Unit Cost	／15
		Linkage to National Road Network - Number and Class of connected roads	／10
2	Social Characteristic, e.g. Population, Production Centers, Social Services	Population/Settlement within 2km of Road	／15
		Rate Production Centre - Markets, factories, farms, etc. within 2km of the road	／10
		Number of Schools/Health within 2km of the Road	／10
3	Road Condition	Pot hole, rutting, drainage, etc.	／30
		Total	／100

Source: MoWT's counterpart and JICA Project Team

The evaluation items and point allocation shown in Table 1-3 were set by MoWT's C/P and JICA expert through the Project. These evaluation items and point allocation can be appropriately modified or updated according to road characteristics and regional characteristics of regions of the country.

In addition, there is an example of indicators that are effective in quantitatively judging the need for repair based on the degree of cracks and ruts on asphalt paved roads, which is shown in Figure 1-7 for reference.

Calculation MCI $MCI_0=10-1.5C^{0.3}-0.3D^{0.7}$

Crack ratio \ Rutting			1	2	3	4	5	6	7	8	9
			0-5 mm	5-10 mm	10-15 mm	12-20 mm	20-25 mm	25-30 mm	30-35 mm	35-40 mm	Over 40mm
			2.5	7.5	12.5	17.5	22.5	27.5	32.5	37.5	40
1	0-5%	2.5	7.456	6.796	6.268	5.801	5.373	4.973	4.594	4.233	4.058
2	5-10%	7.5	6.685	6.025	5.497	5.03	4.602	4.202	3.823	3.462	3.287
3	10-15%	12.5	6.23	5.571	5.042	4.575	4.147	3.747	3.369	3.007	2.832
4	12-20%	17.5	5.89	5.231	4.702	4.235	3.808	3.408	3.029	2.667	2.492
5	20-25%	22.5	5.613	4.953	4.425	3.958	3.53	3.13	2.752	2.39	2.215
6	25-30%	27.5	5.376	4.717	4.188	3.721	3.293	2.893	2.515	2.153	1.978
7	30-35%	32.5	5.168	4.508	3.98	3.513	3.085	2.685	2.306	1.945	1.77
8	35-40%	37.5	4.981	4.321	3.793	3.326	2.898	2.498	2.119	1.758	1.583
9	Over40%	40	4.894	4.234	3.706	3.239	2.811	2.411	2.032	1.671	1.496

Source: Maintenance Control Index（MCI）

Figure 1-7 Indicators for Judging Urgency of Repair based on Degree of Damage to Asphalt Pavement (Reference Case)

In the future, when MoWT plans maintenance and rehabilitation of roads under its jurisdiction, it is recommended to utilize the local road database developed by the past JICA project. The database is updated by maintenance and rehabilitation work performed, and by periodically reviewing the accumulated data, it is possible to comprehensively grasp maintenance history, etc. and thus can be effectively used for prediction of a next maintenance period and planning.

2. Improvement of Efficiency of Road Maintenance

Figure 1-8 is an example of equipment operation record collected by the GPS tracking system installed in the KOMATSU excavator owned by MoWT. This data shows information of the location of equipment, the number of working days, working hours, travel hours, fuel consumption, etc., and it shows the following reality.

a) Remarkable gap between busy period and non-busy period in road maintenance work
b) Over burden on equipment due to a long-distance travel of heavy equipment (e.g. excavators, bulldozers, rollers) that are not suitable for self-propulsion
   (Note: For example, the manufacturer of excavator recommends self-propulsion within only 5 km per movement.)
c) Inefficient fuel consumption due to long-distance travel of heavy equipment

Date	Working Status (Monthly)	Working Days	Working Hours	Actual Working Hrs.	ATT	Travel	Daily Avg.	Amount of Fuel Consumed
12/2022		8 Days	10H	8.1H	0H	2.3H	1.2H	112.8L
11/2022		15 Days	46H	40.7H	0H	25.1H	3H	683L
10/2022		22 Days	94H	80H	0H	25.7H	4.2H	1235.9L
09/2022		11 Days	39H	33.5H	0H	13.4H	3.5H	552L
08/2022		4 Days	11H	10.2H	0H	2.6H	2.7H	187.2L
07/2022		11 Days	31H	26.6H	0H	2.9H	2.8H	419.1L
06/2022		24 Days	97H	81.5H	0H	30.9H	4H	1418.6L
05/2022		23 Days	100H	86.4H	0H	19.9H	4.3H	1590.2L
04/2022		18 Days	102H	89.5H	0H	20.6H	5.6H	1596.4L
03/2022		22 Days	115H	97.9H	0H	20.4H	5.2H	1712.6L
02/2022		9 Days	6H	1H	0H	0.5H	0.6H	22.1L
01/2022		20 Days	16H	4.1H	0H	1.5H	0.8H	75.8L

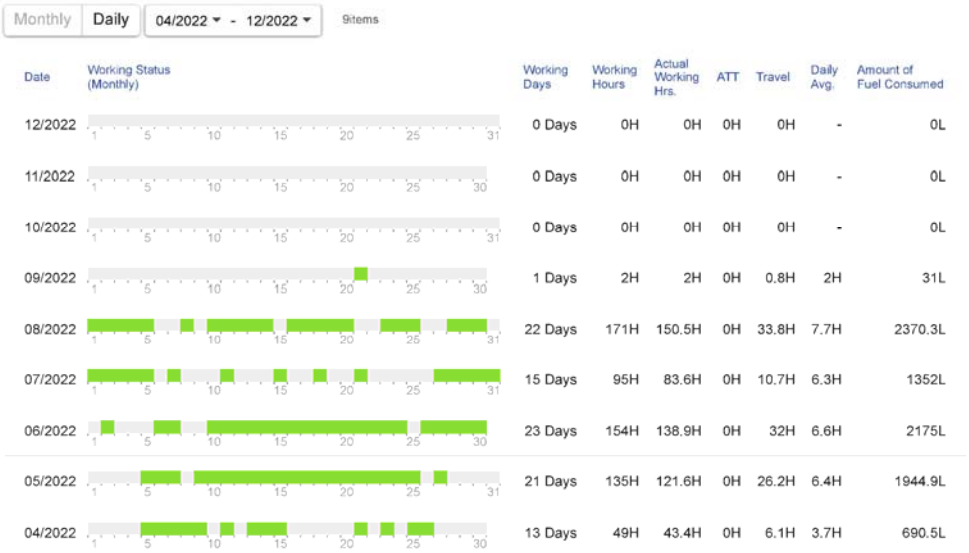
Source: Collected data from the GPS tracking system of excavator (PC220-8M0)

Figure 1-8 Example of Operation Record of Excavator collected from GPS Tracking System

In the case of the excavator shown in Figure 1-8, the number of working days in the first half of the fiscal year (July 1st to December 31st) is lower than in the second half, and the number of working days increases in the second half (January 1st to June 30th of the following year). Other excavators owned by MoWT also show large discrepancies in the number of working days per month. In particular, since the operation rate in the first half tends to be lower than in the second half, it is desirable to level the work volume of road maintenance throughout the year.

Moreover, as shown in Figure 1-8, travel hour accounts for a large proportion of the total working hours of equipment. This shows the fact that an excavator that is not suitable for self-propelled movement is moved over a long distance by self-propelled propulsion. Such long-distance self-propelled operation by the operator not only puts an excessive load on the undercarriage of equipment, shortening the life of equipment, but also increases costs due to inefficient fuel consumption.

Here, the data shown in Figure 1-9 is an example of the excavator that has been waiting for repair for a long time without replacing spare parts of the undercarriage system.



Date	Working Status (Monthly)	Working Days	Working Hours	Actual Working Hrs.	ATT	Travel	Daily Avg.	Amount of Fuel Consumed
12/2022		0 Days	0H	0H	0H	0H	-	0L
11/2022		0 Days	0H	0H	0H	0H	-	0L
10/2022		0 Days	0H	0H	0H	0H	-	0L
09/2022		1 Days	2H	2H	0H	0.8H	2H	31L
08/2022		22 Days	171H	150.5H	0H	33.8H	7.7H	2370.3L
07/2022		15 Days	95H	83.6H	0H	10.7H	6.3H	1352L
06/2022		23 Days	154H	138.9H	0H	32H	6.6H	2175L
05/2022		21 Days	135H	121.6H	0H	26.2H	6.4H	1944.9L
04/2022		13 Days	49H	43.4H	0H	6.1H	3.7H	690.5L

Source: Collected data from the GPS tracking system of excavator (PC220-8M0)

Figure 1-9 Excavator Out Of Service after October 2022

Based on the above finding, as an initiative to improve the excessive load on equipment typified by long-distance self-propelled propulsion and inefficient fuel consumption, as well as to optimize road maintenance costs, the action plan shown in Table 1-4 was formulated. This action plan was made by participants from the civil team and the mechanical team in the joint workshop held during the Project.

Table 1-4 Challenges, Resolutions and Responsible Entity/Persons in Road Maintenance Using Equipment

S/N	CHALLENGES	RESOLUTIONS	RESPONSIBLE ENTITY /PERSONS
1	Wear of undercarriage	➢ Long Equipment travel should be avoided ➢ Plan for the shifting of the equipment	➢ Plant operator ➢ Civil engineer and mechanical foremen
2	Use of equipment when it is overdue for service	➢ Equipment should be parked whenever it is due for service. ➢ Service should only be under taken by trained persons.	➢ Regional mechanical workshops ➢ Plant operators ➢ Mechanical foremen
3	Political pressure	➢ All political request should be official.	➢ Permanent secretary ➢ Engineer in chief ➢ Regional managers
4	Lack of komtrax information	➢ All managers and mechanical foremen should liaise with TOT-mechanics and registered personnel	➢ TOT-Mechanics
5	Over consumption of fuel	➢ Follow up on fuel consumption by use of KOMTRAX ➢ Operators should be encouraged to use Eco mode when in normal operating situation	➢ TOT mechanics and registered personnel.

Source: Prepared by the participants of the joint workshop

The achievement status of the action plan shown in Table 1-4 above can be monitored by the recorded data of the GPS tracking system.

3. Measures for Cost Reduction of Road Construction

(1) Optimization of Pavement Structure according to Traffic Demand

During site investigations in the Project, JICA expert was aware of some cases where hot-mix asphalt pavement with a thickness of 3 inches (= 7.62 cm) is applied to the surface layer on District Roads around residential areas. As long as JICA expert surveyed the traffic condition around such residential areas, the daily traffic volume was less than 500 vehicles on many routes, and there were no heavy vehicles at all. Roads in these residential areas are unlikely to see an increase in the number of heavy vehicles in the future except the case that there is particularly traffic demands to increase.

For such traffic conditions, the asphalt pavement of 3 inches in thickness is excessive increasing construction costs. For the above traffic volume, a surface layer thickness of about 2 inches (= 5.08cm) is considered sufficient according to the pavement design in Japan. By reviewing the thickness in the pavement design, construction costs can be reduced by about 20%.

For reference, Table 1-5 shows examples of pavement structures in multiple cases according to the traffic volume in Japan, and Annex 1 shows the design calculation of pavement thickness for each case. Also, a technical reference on pavement structures to be considered in wetlands with high groundwater levels is

enclosed in Annex 1 for the pavement design. The planned traffic volume applied to the pavement design reflects the traffic demand forecast after the road opened.

Table 1-5 Example of Pavement Structure according to Traffic in Case of Japan

Traffic Volume (2 direction)	Vehicle Type	Design CBR (%)	Surface Asphalt Concrete	Base Course Graded Crushed Stone M-30	Sub base Course Crushed Stone C-40	Total (cm)	Remarks
200 vehicles/day	Light 190 Heavy 10	4	5	10	20	35	
		6	5	10	15	30	Minimum
		8	5	10	15	30	Minimum
300 vehicles/day	Light 285 Heavy 15	4	5	15	20	40	
		6	5	10	20	35	
		8	5	10	15	30	Minimum
500 vehicles/day	Light 475 Heavy 25	4	5	15	25	45	
		6	5	15	20	40	
		8	5	10	20	35	
1,000 vehicles/day	Light 950 Heavy 50	4	5	15	30	50	
		6	5	15	25	45	
		8	5	15	20	40	

Note
Narrow Road: 1-lane road 5-6 m wide
Heavy Vehicle: 10-ton Truck
Light Vehicle: 2-ton passenger car or light truck
Source: JICA Project Team

In addition, other alternative for cost reduction is bituminous surface treatment by the Penetration Macadam Method. The features of the Penetrating Macadam method are shown below.

- Since the materials used are bitumen (asphalt) and aggregate, there is no need to manufacture a hot-mix asphalt material at an asphalt plant, so the manufacturing cost of hot-mix asphalt is unnecessary. Moreover, the amount of materials used is also less than that of hot-mix asphalt materials.
- No asphalt finisher is required for construction. Therefore, transportation costs for construction equipment and fuel costs can be greatly reduced.
- There is no need to lay hot-mix asphalt materials, and construction efficiency can be improved by accumulating skills for spreading bituminous material and surface layer aggregates.
- Since spreading aggregates and bituminous materials can be done manually, construction with Labor-based Technology is also possible, which is expected to further cost reduction and create employment opportunities.

Figure 1-10 and Figure 1-11 show an example of pavement structure and construction reference photographs of bituminous surface treatment by the Penetration Macadam Method

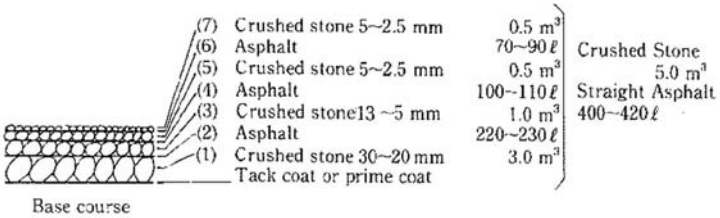


Figure 1-10 Example of Cross Section of Bituminous Surface Treatment

Note: The upper part of the figure shows mechanical construction, and the lower part shows manual construction.
Source: JICA Project Team

Figure 1-11 Construction Procedure of Bituminous Surface Treatment

(2) Combined Use of the Labor-based Technology Method

Considering the limited annual budgets of MoWT and local governments for road maintenance, District Roads and Community Access Roads which have a daily traffic volume of less than 500 vehicles, except the case of large-scale damage caused by heavy rainfall, it is recommended to extend the service life of passable road by maintaining roads with small-scale road surface repairing and cleaning work regularly or on daily basis.

In the case of road construction using construction equipment, in addition to the cost of construction materials such as aggregate and asphalt, the cost of fuel to operate equipment accounts for a large proportion of the total construction cost. Therefore, for work that can be carried out mainly by labor, the use of Labor-based Technology (LBT) in addition to Equipment-based Technology (EBT) can reduce the cost of equipment mobilization and fuel, and is expected to significantly reduce road maintenance costs.

Figure 1-12 shows a typical work flow of road maintenance and rehabilitation by LBT.

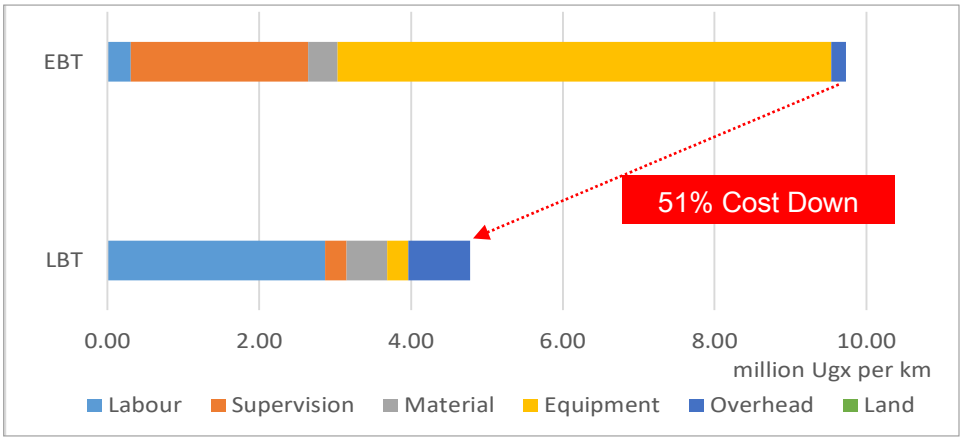
Source: Related document for LBT

Figure 1-12 Work Flow of Road Maintenance with LBT

The following conditions are listed as regional characteristics suitable for road maintenance by LBT.

- The site is a rural area with a large population and a large unemployed population. (Not limited to unemployed people)
- Daily traffic volume is low (About 500 vehicles or less)
- There is a need for road maintenance by local immigrants, but it is considered to be a low priority due to budget constraints.

Next, in the past study in Uganda, road maintenance costs by LBT and EBT were compared and explained as shown in Figure 1-13.



Unit: million Ugx / km

	Labour	Supervision	Material	Equipment	Overhead	Land	Total
LBT	2.87 (60.0%)	0.28 (5.9%)	0.54 (11.2%)	0.28 (5.8%)	0.82 (17.1%)	0.00 (0.0%)	4.78 (100%)
EBT	0.31 (3.2%)	2.34 (24.0%)	0.39 (4.0%)	6.50 (66.8%)	0.19 (2.0%)	0.00 (0.0%)	9.73 (100%)

Source: An Opportunity for Employment Creation, Labour-based Technology in Roadworks, UGANDA, June 1999

Figure 1-13 Cost Reduction Data with LBT in the Past Study

According to the above figure, in the case of EBT, the equipment cost accounts for about 2/3 (66.8%) of the construction cost, while in the case of LBT, labor costs account for about 2/3 (60.0%). Also, by applying LBT, the construction cost per km was reduced by 51%. Although the study was validated by sampling a specific rural road in Uganda, the clear conclusion is that LBT reduces costs.

From the above, the effectiveness of LBT application is recognized as long as it is a regional road that meets the conditions listed above. By implementing work that can be done mainly by human power at low cost, it is expected that emphasis will be placed on the construction of structures such as box culverts and small bridges at places where traffic is bottlenecked due to insufficient drainage.

While sufficient management skills are required of on-site leaders in developing LBT, the human resources of road managers are also limited, so it is necessary to create a system that involves private construction companies and local communities.

4. Measure for Cleaning and Maintenance of Drainage Facility

At present, drainage pipe cleaning in Kampala City involves workers entering the pipes and manually scraping out sediments. In Kampala City, especially after rainfall during the rainy season, sediment from the hillsides flows downstream, causing sediment to accumulate in the drainage pipes and ditches, which in turn causes the drainage facilities to malfunction and flood the roads.

In the future, there is room to consider more efficient means of cleaning and maintenance of drainage facilities, depending on the amount of work and the degree of sediment deposition.

For reference, Figure 1-14 shows an example of equipment that enables mechanized cleaning and maintenance of drainage facilities.

Figure 1-14 High-pressure Drainage Cleaning Vehicle (Left) and Sludge Suction Truck (Right)

Chapter 2. Recommendations on Management of Road Maintenance Equipment

1. Scope of Mechanical Services of MoWT Workshop

In order for MoWT to properly operate and maintain its equipment, it is important to actively utilize private sector services for equipment maintenance, considering the structural characteristics of road equipment, which have recently become more complex due to electronic control, and the existing facilities, equipment, and personnel structure of the MoWT mechanical workshop. Table 2-1 shows the scope of mechanical services that are directly implemented by MoWT, as well as the scope that utilize private services.

Table 2-1 Scope of Mechanical Services to be undertaken by MoWT and Private Sector

Service level	Type of equipment servicing and repair	Main work items	Demarcation		
			MoWT		Manufacturer / Local Dealer
			Central Workshop	Regional Workshops	
1 Light	Periodical Maintenance	Change lubricants, lubrication	○	○	
2	Inspection and adjustment	Adjusting brake, adjusting clutch etc.	○	○	
3	Minor repair and maintenance	Replacement of consumable parts	○	○	
4	Overhaul of the main component	Engine, clutch, transmission, hydraulic component etc. (mechanical component/device)	△ Note 1	△ Note 1	○
		Undercarriage of construction equipment (part replacement) Note 2	○	○	○
5 Heavy	Trouble shooting and repair of electronic component /device	Electric/electronic/hydraulic control system, for engine, power train and hydraulic component etc.			○
6	Major overhaul and repair, and modifications	Major overhaul/repair of equipment and modifications			○

Note 1: MoWT has experience and achievements for small vehicles. Therefore, a repairing work of small vehicles are classified as MoWT's direct operation.

Note 2: Replacement of parts around the undercarriage of construction equipment is going to be carried out by MoWT directly or by utilizing private service, depending on the content of maintenance and MoWT's budgetary conditions.

Source: Prepared by MoWT and the Project Team

Table 2-1 above was developed through consultation between MoWT and JICA Project Team throughout the Project. It is recommended that MoWT maintain a close communication and reporting system with local dealers and continue equipment maintenance and repair based on the work classification indicated in this table.

2. Annual Maintenance Costs estimated for Service Life of Equipment

As of 2023, more than five years will have passed since MoWT procured 1,152 units of Japanese equipment in 2017 through a JBIC loan, which will increasingly require equipment maintenance.

Table 2-2 shows the regular and irregular maintenance items expected over the life of equipment.

Table 2-2 Items of Equipment Maintenance

Classification	Service time	Maintenance items
Regular	250-500 hours	Engine oil, hydraulic oil, engine oil filter, fuel filter, grease (as needed)
	2,000～2,500 hours	Reversal (reuse) of pins and bushings of equipment (bulldozers, hydraulic excavators) that travels with a crawler system
	3,500～4,000 hours	Replacement of undercarriage parts for equipment (bulldozers, hydraulic excavators) that run on crawler system
	per constant consumption	Vehicle tire replacement, construction machinery tooth and edge replacement
Irregular	—	Maintenance and repair of engines (overhaul), transmissions, hydraulic pumps, motors, hydraulic cylinders, brakes, cooling systems, air conditioners, body sheet metal, glass, etc.

Source: JICA Project Team

In order to implement the maintenance items shown in Table 2-2 above in a timely manner, it is essential to allocate the necessary annual budget over the service life of equipment. Table 2-3 shows the anticipated annual maintenance costs for Japanese equipment procured by MoWT in 2017.

Table 2-3 Anticipated Annual Maintenance Costs

	Name of Equipment	Machine's life span (years)	Mainte. cost Rate (in life span) (%)	Total mainitenace cost (JPY/unit)	Av. mainte. cost/year (JPY/unit)	Mainte. cost for remained years (JPY/unit)	Mainte. cost per year for remained years (JPY per year/unit)	Number of equipment (unit)	Total mainte. cost per year for remained years (JPY)
1	Morter Grader GD663-2	10	55	10,450,000	1,045,000	6,270,000	1,254,000	143	179,322,000
2	Wheel Loader WA250-5	10	40	7,200,000	720,000	4,320,000	864,000	122	105,408,000
3	Wheel Loader WA430-5	10	30	9,600,000	960,000	5,760,000	1,152,000	13	14,976,000
4	Excavator PC220-8 Standard	10	55	13,750,000	1,375,000	8,250,000	1,650,000	21	34,650,000
5	Excavator PC220-8 Long-Boom	10	55	14,850,000	1,485,000	8,910,000	1,782,000	0	0
6	Bulldozer D65EX-16	10	55	15,400,000	1,540,000	9,240,000	1,848,000	25	46,200,000
7	Wheel Backhoe Loader	10	50	6,700,000	670,000	4,020,000	804,000	31	24,924,000
8	Vibratory Roller 10ton SV520D	10	40	3,360,000	336,000	2,016,000	403,200	141	56,851,200
9	Pneumatic Tyre rollor TS200	10	45	2,574,000	257,400	1,544,400	308,880	4	1,235,520
10	Pedestrain Roller 0.8ton HV80	10	40	752,000	75,200	451,200	90,240	18	1,624,320
11	Plate compactors 4.3Hp PC63	7	40	100,000	14,286	60,000	30,000	20	600,000
12	Tampers/Rammers RS55E	7	30	96,300	13,757	57,780	28,890	18	520,020
13	Dump Truck 8ton	10	30	3,600,000	360,000	2,160,000	432,000	276	119,232,000
14	Dump Trucks with chip spreader	10	30	4,050,000	405,000	2,430,000	486,000	7	3,402,000
15	Cargo Truck 8ton	10	45	4,686,746	468,675	2,812,048	562,410	9	5,061,686
16	Water bowser 8,000L	10	45	4,934,798	493,480	2,960,879	592,176	138	81,720,249
17	Low bed tructor pay load 30ton	10	35	12,600,000	1,260,000	7,560,000	1,512,000	9	13,608,000
18	Self-loading truck pay load 15ton	10	45	11,250,000	1,125,000	6,750,000	1,350,000	21	28,350,000
19	Mobile Workshop	10	50	9,000,000	900,000	5,400,000	1,080,000	5	5,400,000
20	Mobile crane 35ton	10	25	10,750,000	1,075,000	6,450,000	1,290,000	1	1,290,000
21	Bitumen Distributor	10	30	5,980,914	598,091	3,588,548	717,710	4	2,870,839
22	Bulldozer D85EX-15R	10	40	12,800,000	1,280,000	7,680,000	1,536,000	0	0
23	Tandem roller CR271 1.44ton	7	30	660,000	94,286	396,000	198,000	4	792,000
24	Vibratory Roller 15ton SV700	7	35	7,007,000	1,001,000	4,204,200	2,102,100	0	0
25	Vibratory Roller 18ton SV700	7	45	9,900,000	1,414,286	5,940,000	2,970,000	0	0
26	Double drum Vibratory Tandem Roller	7	50	6,545,000	935,000	3,927,000	1,963,500	1	1,963,500
27	Tandem roller SW800 10.4ton	7	25	3,325,000	475,000	1,995,000	997,500	0	0
28	Vibrator combinmed roller TW504	7	30	1,650,000	235,714	990,000	495,000	1	495,000
Total in JPY							**28,499,605**		**730,496,334**
Total in USD							**219,228**		**5,619,203**

Reference exchange rate: USD1 = JPY130
Source: JICA Project Team

The annual maintenance costs shown in Table 2-3 above are calculated based on standard actual data in Japan, and actual maintenance costs will depend on the environment in which the equipment is used, construction conditions, and other factors. However, it is recommended that MoWT is aware that the above amount scale is necessary and reflect it in its annual budget application as appropriate.

3. Countermeasure for Urgent Issue on Equipment Maintenance

Among the maintenance items shown in Table 2-2, the one that requires particularly large maintenance costs is the crawler system; as of January 2023, bulldozers and excavator traveling with the crawler system have been in operation for more than 3,000 hours, exceeding the allowable wear of the undercarriage.

Therefore, maintenance of the undercarriage is urgently needed to maintain the functionality of the crawler system. Specifically, undercarriage parts must be replaced with new spare parts or reused by taking measures to recondition undercarriage parts. Otherwise, extreme wear of the undercarriage components will render the equipment inoperable.

Table 2-4 shows the list of locations and necessary measures for 25 bulldozers and 23 Excavators under the management of MoWT.

Table 2-4 List of Bulldozer and Excavator with Locations and Necessary Measures

No.	Location	Model	Unit	Necessary Measures
1	Kampala	Bulldozer (D65EX-16)	5 units	Replace with new spare parts for the undercarriage, or rebuild those parts by using the undercarriage rebuilding equipment
		Excavator (PC220-8)	5 units	Ditto
2	Bugembe	Bulldozer (D65EX-16)	8 units	Ditto
		Excavator (PC220-8)	8 units	Ditto
3	Gulu	Bulldozer (D65EX-16)	6 units	Ditto
		Excavator (PC220-8)	5 units	Ditto
4	Mbarara	Bulldozer (D65EX-16)	6 units	Ditto
		Excavator (PC220-8)	5 units	Ditto

Source: JICA Project Team

The estimated cost of MoWT's future purchases of spare parts for the undercarriage is shown in Table 2-5.

Table 2-5 Estimated Cost for Renew of Undercarriage Spare Parts

Unit: UGX [Note1]

No.	Equipment	Model	Unit Rate	Q'ty	Amount
1	Excavator	KOMATSU PC-220-8 Standard	146,500,000	21 (30)	3,076,500,000 (4,395,000,000)
2	Excavator	KOMATSU PC-220-8 Long Boom	146,500,000	0 (3)	0 (439,500,000)
3	Bulldozer	KOMATSU D65EX-15	182,500,000	25 (31)	4,562,500,000 (5,657,500,000)
4	Bulldozer	KOMATSU D85EX-15R	219,000,000	0 (2)	0 (438,000,000)
				Total	7,639,000,000 (10,930,000,000)

Note 1: Reference exchange rate: UGX1,000 = JPY37 (as of May 2023)
Note 2: Figures in parentheses for quantity and amount are totals including equipment under the control of UNRA and NEC, and figures outside the parentheses are the total extracted only for equipment under the control of MoWT.
Source: JICA Project Team

Next, Table 2-6 shows the estimated cost of reusing undercarriage parts by using the undercarriage rebuilding equipment. In this case, MoWT needs to procure the undercarriage rebuilding equipment, and the initial cost for procurement is estimated to be about UGX6,400,000,000 (approximately USD1,700,000).

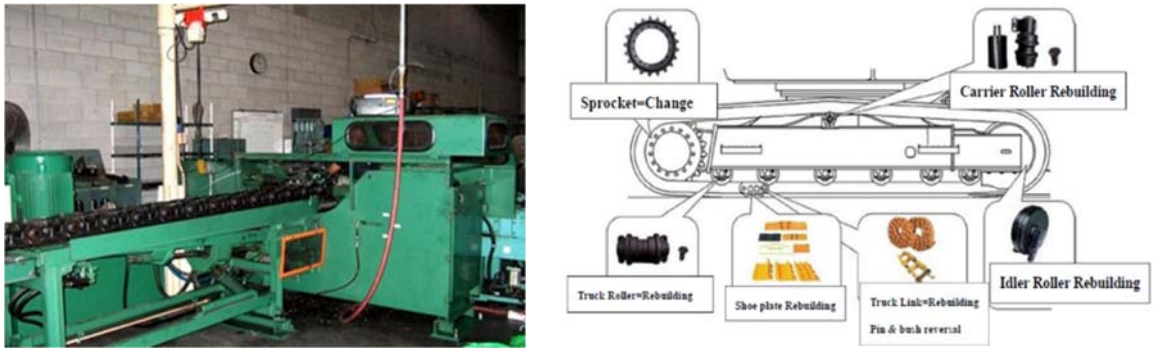
Table2-6 Estimated Cost for Reusing Undercarriage Parts by Undercarriage Rebuilding Equipment

Unit: UGX [Note1]

No.	Equipment	Model	Unit Rate	Q'ty	Amount
1	Excavator	KOMATSU PC-220-8 Standard	116,830,000	21 (30)	2,453,430,000 (3,504,900,000)
2	Excavator	KOMATSU PC-220-8 Long Boom	116,830,000	0 (3)	0 (350,490,000)
3	Bulldozer	KOMATSU D65EX-15	146,777,000	25 (31)	3,669,425,000 (4,550,087,000)
4	Bulldozer	KOMATSU D85EX-15R	175,200,000	0 (2)	0 (350,400,000)
				Total	6,122,855,000 (8,755,877,000)

Note 1: Reference exchange rate: UGX1,000 = JPY37 (as of May 2023)
Note 2: Figures in parentheses for quantity and amount are totals including equipment under the control of UNRA and NEC, and figures outside the parentheses are the total extracted only for equipment under the control of MoWT.
Source: JICA Project Team

Figure 2-1 shows a reference photograph of the undercarriage rebuilding equipment and various parts that can be reused with this equipment.



Source: JICA Project Team

Figure2-1 Undercarriage Rebuilding Equipment (Left) and Parts that can be reused

The advantages in case that MoWT procures the undercarriage rebuilding equipment are shown below.

- Although initial investment costs are required to procure the undercarriage rebuilding equipment, once procured, costs can be reduced continuously compared to purchasing new spare parts.
- The undercarriage rebuilding equipment is a general-purpose product that is not limited to compatible manufacturers, so it can be used for a wide range of equipment with the crawler system.

After procurement of the undercarriage rebuilding equipment, a cost reduction of approximately 2.17 billion UGX will be possible for the undercarriage maintenance of 46 units (21 Excavators and 25 bulldozers) under MoWT's management, and it can also be used for equipment with the crawler system to be procured by MoWT in the future. Therefore, continuous cost reductions can be expected over the long term through the maintenance by using the undercarriage rebuilding equipment.

However, as mentioned at the beginning of this section, undercarriage maintenance is an urgent issue. Therefore, if it takes time to procure the undercarriage rebuilding equipment, new spare parts should be purchased and replaced with old parts as an immediate measure.

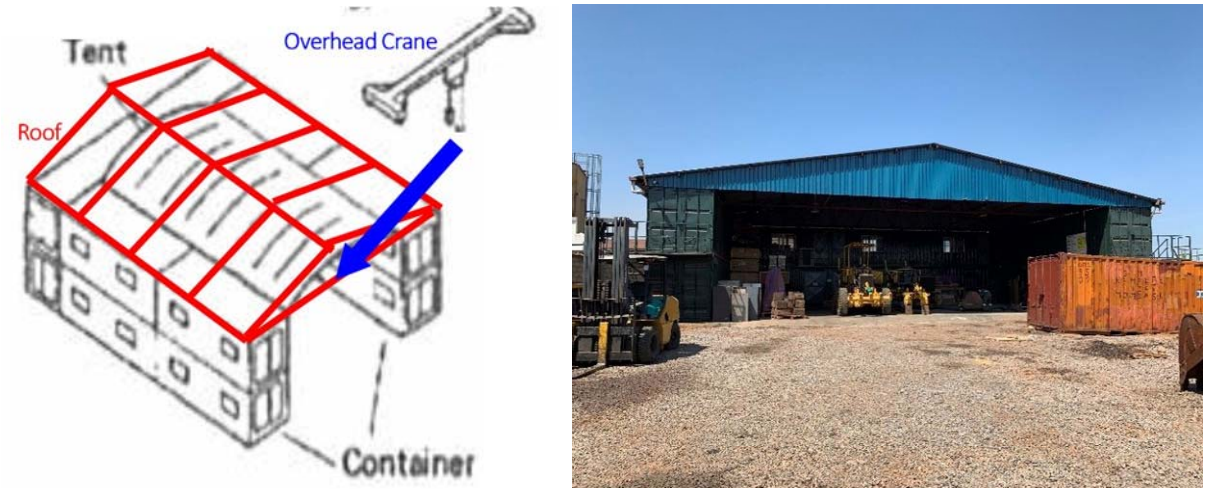
4. Upgrading of MoWT's Mechanical Workshop

Of the four Central and Regional Mechanical Workshops (i.e. Kampala, Bugembe, Gulu, and Mbarara) under MoWT, except for the Bugembe Regional Mechanical Workshop which was developed in 1996 with Japanese grant aid, other three workshop have insufficient facilities and equipment.

Under such circumstances, it is considered that existing facilities and equipment can provide a minimum level of service for the time being to cover the mechanical service categories directly managed by MoWT shown in Table 2-1. However, the frequency of equipment maintenance and repair is expected to increase as time goes by, and it is assumed that the existing facilities and equipment will eventually need to be upgraded. On the other hand, assuming the use of private services as defined in Table 2-1, planning excessive facility and equipment specifications for maintenance shops to be renewed in the future will lead to an increase in initial maintenance costs.

Based on the above, one measure, especially for the Mechanical Workshops in Gulu and Mbarara, which are regional organizations, is to establish compact and simple mechanical workshops that can provide equipment services based on the implementation categories in Table 2-1.

Figure 2-2 shows an example of a simple mechanical workshop.



Source: JICA Project Team (Lett), photograph of mechanical workshop of local dealer (Right)

Figure 2-2 Example of Simple Mechanical Workshop

As shown in the figure above, a simple mechanical workshop building can be constructed with a perimeter wall of containers, and the inside of the containers can be used as an office and work space. Such a simple workshop is recommended as a realistic scale of development for local workshops under the constraints of MoWT's annual budget, since it can reduce not only the initial construction cost but also operation and

maintenance costs. For reference, the estimated costs for updating the MoWT Mechanical Workshop, including the simple container workshop, are shown in Annex 2.

5. Utilization of the GPS Tracking System

As mentioned in "2. Improvement of Efficiency of Road Maintenance" the recorded data from the GPS tracking system of the Komatsu excavator reveals a number of activities that cause budget pressures in road maintenance and equipment maintenance, such as long-distance self-propelled-propulsion of heavy equipment unsuitable for self-propelled propulsion and inefficient fuel consumption due to long-distance self-propelled propulsion.

It is recommended that the Department of Mechanical Engineering Services monitors the operational status of equipment as appropriate using a GPS tracking system, and then share the recorded data with the civil team and alert them to the need for proper equipment operation. Optimization of equipment operation will ultimately contribute to improvement of efficiency in road maintenance.

In addition to Komatsu's heavy equipment, the GPS tracking system is also installed on SAKAI's compaction equipment, allowing the location and operational status of each unit of compaction equipment to be monitored remotely.

6. Programme for Training of Mechanics

Table 2-7 shows the program for MoWT to continue training mechanics on its own. The training materials shown in the table are the materials used in TOT of the Project, and MoWT can continue the training by using them.

Table 2-7 Programme for Training of Mechanics

Training Course	Training Items	Training Materialas	Training Period
1. Basic Course (Common) for Vehicle	Subject: Electrical equipment related to the vehicle ➢ The basics of electricity ➢ The basics of electronics. ➢ How to use the circuit tester ➢ How to use the failure diagnosis equipment ➢ Pneumatics and the basics of all pneumatics control circuits ➢ Pneumatics and hydraulic machine maintenance	Following NVTI (NAKAWA Vocational Training Institute) training materials: 1) Diagnosis 2) EWD (Electrical Wiring Diagram) 3) Fundamentals of Electricity 4) Lecture 1 Pneumatic systems 5) Lecture 2 Pneumatic systems	Approx. 5 days or more
2. Basic Course (Common) for Construction Equipment	Subject: Construction equipment ➢ Outline ➢ How to use and teach measuring equipment ➢ Engine ➢ Electrical equipment ➢ Hydraulic system ➢ How to use welding equipment ➢ Undercarriage (wear resistant) ➢ How to do safety slings work ➢ Preparation of technical report for equipment repairing	Following Training Materials: 1) Basic Knowledge_Types and uses of vehicle-based construction machinery 2) Power train (Motor) 3) Hydraulic system 4) Tool and Measurement Instruction Manual	Approx. 5 days or more
3. Advanced Course for Heavy Equipment (KOMATSU)	Subject: Monitor operation and diagnosis method ➢ How to operate the monitor panel of the following equipment ➢ How to do diagnosis using the monitor panel ➢ GPS tracking system utilization method ➢ General maintenance works, etc.	Following Training Materials: 1) FOWA+G 2) Gen Safety & Precautions for Ope and Maintenance 3) General Information for Maintenance 4) PC220-8 Maintenance Outline 5) PC200-8 Checks before starting Maintenance 6) D85EX-15R & D65EX-16 Maintenance Outline 7) D85EX-15R & D65EX-16 Checks before starting Maintenance 8) WA430-5 & WA250-5 Maintenance Outline 9) WA430-5 & WA250-5 Checks before starting Maintenance 10) GD663A-2 Maintenance Outline 11) GD663A-2 Checks before starting Maintenance 12) WB93R-5E0 Maintenance Outline 13) WB93R-5E0 Checks before starting Maintenance 14) Machine Monitor (User mode) 15) PC220-8 Basic Struction & Function 16) D65EX-16 & D85EX-15R Basic Struction & Function 17) WA250-5 & WA430-5 Basic Struction & Function	Approx. 10 days or more

		18) GD663A-2 Basic Struction & Function 19) OMM 20) D65EX-16 OMM 21) D85EX-15R OMM 22) GD663A-2 OMM_1 23) GD663A-2 OMM_3 24) PC220-8M0 OMM 25) WA250-5 OMM 26) WA430-5 OMM 27) WB93R-5E0_OMM 28) POWER POINT - REPORT KOMTRAX (GPS)	
4. Advanced Course for Vehicle (FUSO)	Subject: Proper maintenance operation for compaction equipment; How to maintain, diagnose and repair the following items. ➢ Engine system ➢ Transmission system ➢ Clutch system ➢ Brake system	Following FUSO Training Materials: 1) INTRODUCTION 2) CHASSIS 3) DIESEL ENGINE 4) ELECTRICAL DEVICES 5) ENGINE PARTS 6) FAULT ANALYSIS 7) Pre-Delivery and Periodic Inspection Manual (PDI) 8) TROUBLESHOOTI NG PROCEDURE 1 9) TROUBLESHOOTI NG PROCEDURE 2 10) WORKSHOP SAFETY	Approx. 5 days or more
5. Advanced Course for Compaction Equipment (SAKAI)	Subject: Proper maintenance operation for compaction equipment; How to maintain, diagnose and repair the following items. ➢ Engine system ➢ Transmission system ➢ Hydraulic system ➢ Brake system ➢ Undercarriage	Following SAKAI Training Materials: 1) SV520 series Vibration Roller 2) SV520 Precautions 3) SV520 Fuel System Filters 4) SV520 Periodical Maintenance 5) TS200 Static Pneumatic Tired Roller 6) TS200 Precautions 7) TS200 Periodical Maintenance	Approx. 5 days or more
6. Practical Training Course with OJT	Subject: OJT on the following items. ➢ Measuring equipment ➢ Engine ➢ Electrical equipment ➢ Hydraulic system ➢ How to use welding equipment ➢ How to do safety slings work ➢ Preparation of technical report for equipment repairing	Following Training Materials: 1) Safety in Gas Welding, Cutting and Similar Processes 2) Excavator Grease Supply Position 3) Examination Sheet for Engine 4) Score Evaluation Table for Engine 5) Examination Sheet for Hydraulic Cylinder 6) Score Evaluation Table for Hydraulic Cylinder 7) Examination Sheet for Gas Cutting 8) .Score Evaluation Table for Gus Cutting 9) Construction Machinery Maintenance Practical Test 10) Power Matters 11) Slinging Skill Training Chapter 1 12) Slinging Skill Training Chapter 2 13) List of Training Equipment 14) List of Measurement Equipment	Practical training with OJT through daily work

Source: JICA Project Team

Chapter 3. KPI to be monitored for Sustained Project Effectiveness

MoWT will use the knowledge and skills acquired through the Project to improve the efficiency of road maintenance work and equipment operation and maintenance work through its own activities. In order to sustain such self-reliant development, it is recommended that MoWT continue to monitor the progress of these efforts and issues on its own and share the status of its activities with JICA on a regular basis.

Table 3-1 shows the items that are recommended for continuous monitoring and sharing with JICA.

Table 3-1 Monitoring Items and Objectives

Items	Objectives
1. As for the results of training for mechanics by mechanic instructors, who have completed the TOT of the Project, including the time of implementation, participants, and training results (number of trainees who completed the training, field of study, etc.). (Note: When the instructor retires, it is advised to share this information with JICA along with the status of the appointment and succession of his/her successor.)	The planned and continuous training of mechanics is important for MoWT to maintain and improve its organizational capacity to properly maintain and repair its equipment.
2. Monitoring results from the GPS tracking system, including the number of working days and hours the equipment was in operation, and the percentage of time in self-propelled-propulsion on its own to the total working hours.	Improving the excessive load on equipment and inefficient fuel consumption, as typified by long-distance self-propelled propulsion, will help extend the life of equipment and, ultimately, optimize road maintenance costs. It is important that the civil and equipment teams work together to monitor and continue to follow the Action Plan defined as Table 1-4.
3. Progress of updating the Database of District and Urban Roads, and completion reports of road maintenance and rehabilitation works as supplementary explanatory documents when needed. （Note: Standard MoWT forms are acceptable for completion reports.）	Comprehensive ledger management through the Database is an effective means for forecasting the timing of road maintenance and rehabilitation, and for planning and budgeting.
4. Status of preparation and reporting of the technical report on equipment maintenance and repair (see Annex 3). (Note: When sharing reports with JICA, it is acceptable to extract only some typical case examples, not all reports)	Precise reporting of equipment maintenance and repair records through the technical report format is not only a means of reporting equipment condition within the MoWT organization, but is also important for the effective use of private services by sharing them with dealers as needed.

Source: JICA Project Team

The above mentioned 4 items are the Key Performance Indicator (KPI) for MoWT to quantitatively confirm the achievement status of its future efforts. Continuous monitoring of these items is an effective means for MoWT to visualize its progress toward achieving its goal of improving the efficiency of road maintenance through the training and capacity building of road engineers, equipment managers, mechanics, and others, and through the proper use of its equipment.

In addition, this continuous self-reliant development will help to encourage a sense of ownership as the highest level organization in road administration of the country of Uganda.

END

Example of Pavement Design in Japan

Traffic Volume: 200 vehicles per day, Design CBR: 4%

1 Pavement Structure Design

1.1 Target pavement thickness

The pavement design is based on the TA method used in Japan.

Target pavement thickness is calculated using formula (1.1) based on the Cumulative number of wheels equivalent loads to 5 tons during the design period (N) and the CBR of the subgrade.

$TA=3.84\ N^{0.16} / CBR^{0.3}$ (formula 1.1)

TA : Total pavement thickness converted into an equivalent thickness of hot mix asphalt concrete (cm)

N : Cumulative number of wheels equivalent loads to 5 tons during the design period

CBR : Subgrade CBR (%)

$N=\sum_{i=1}^{n}(N(5\text{ tons}) \times 365 \times ai)$ (formula 1.2)

N : Cumulative number of wheels equivalent loads to 5 tons during the design period

N(5 tons) : Number of equivalent wheel loads of each vehicle/ day

$N(5\text{ tons})=(\text{Wheel loads}/5)^4 \times \text{Number of wheels}$

n : Design Period (normally 10 years)

ai: Traffic Growth Ratio

2 Target Total Pavement Thickness (TA)

2.1 Design Condition

Traffic Volume	200	Vehicles/day	Light Vehicle	190	Vehicles/day	95 %
			Heavy Vehicle	10	Vehicles/day	5 %
Design Period	10	years				
Traffic Growth Ratio	3	%				
Subgrade CBR	4	%				

2.2 Light Vehicle N (5 tons) 2- ton Passenger Car or Light Truck

0.5 ton	0.5 ton
0.5 ton	0.5 ton

Light Vehicle N (5 tons) $= 4 \times (0.5/5)^4$

$= 0.0004$

2.3 Heavy Vehicle N (5 tons) 10- ton Heavy Truck

1.0 ton	4.0 ton
1.0 ton	4.0 ton

Heavy Vehicle N (5 tons) $= 2 \times (1.0/5)^4 + 2 \times (4.0/5)^4$

$= 0.823$

2.4 Cumulative number of wheels equivalent loads to 5 tons during the design period（N）

$$N = \Sigma_{i=1}^{10} \left(190 \times 0.0004 + 10 \times 0.823 \right) \times 365 \times \left(1.03 \right)^{i}$$

$$= 34{,}755$$

2.5 Calculation of TA

$$TA = 3.84 \times \left(34{,}755 \right)^{0.16} / \left(4 \right)^{0.3}$$

$$= 13.5$$

3 Conversion Coefficient

Table 3.1 shows conversion coefficient of pavement structure.

Table 3.1 Conversion Coefficient of pavement Structure.

Pavement Structure		Conversion Coefficient
Asphalt Surface Course		1.00
Base Course	(M-30)	0.35
Bab-base Course	(C-40)	0.25

4 Pavement Structure

4.1 Design Pavement Structure

The pavement three layers: asphalt surface, base course, and sub-base course. Table 4.1 shows minimum thickness of each layer. TA' obtained by multiplying the thickness of each layer by the conversion coefficient shall be set to be equal to or greater than TA.

$TA' = a1T1 + a2T2 + a3T3$ （Formula 4.1）

$TA' \geqq TA$

Table 4.1 Minimum Thickness Each Pavement Structure

Pavement Structure		Minimum Thickness
Asphalt Surface Course		5cm
Base Course	(M-30)	10cm
Bab-base Course	(C-40)	12cm

Note: minimum thickness is 3 times of stone size

4.2 Design of Pavement Thickness

Table 4.2 shows the design pavement thickness (cm) of the three layers of the asphalt surface, base course, and sub-base course.

Table 4.2 Design of Pavement Structure

Pavement Structure		Pavement Thickness
Asphalt Surface Course		5 cm
Base Course	(M-30)	10 cm
Bab-base Course	(C-40)	20 cm

$TA' = 5 \times 1.0 + 10 \times 0.35 + 20 \times 0.25$

$13.5 \geqq TA = 13.5$

$TA' \geqq TA$

Since TA' exceeds TA, the layer thickness in Table 4.2 is used as the design pavement thickness.

N: Cumulative number of wheels equivalent loads to 5 tons during 10 years

1	(	0.0004	x	190	+	0.823	x	10	)	x 365					3,032
2	(	0.0004	x	190	+	0.823	x	10	)	x 365	x	(	1.03	)	3,123
3	(	0.0004	x	190	+	0.823	x	10	)	x 365	x	(	1.03	$)^2$	3,216
4	(	0.0004	x	190	+	0.823	x	10	)	x 365	x	(	1.03	$)^3$	3,313
5	(	0.0004	x	190	+	0.823	x	10	)	x 365	x	(	1.03	$)^4$	3,412
6	(	0.0004	x	190	+	0.823	x	10	)	x 365	x	(	1.03	$)^5$	3,515
7	(	0.0004	x	190	+	0.823	x	10	)	x 365	x	(	1.03	$)^6$	3,620
8	(	0.0004	x	190	+	0.823	x	10	)	x 365	x	(	1.03	$)^7$	3,729
9	(	0.0004	x	190	+	0.823	x	10	)	x 365	x	(	1.03	$)^8$	3,840
10	(	0.0004	x	190	+	0.823	x	10	)	x 365	x	(	1.03	$)^9$	3,956

N = 34,755

Traffic Volume: 200 vehicles per day, Design CBR: 6%

1 Pavement Structure Design

1.1 Target pavement thickness

The pavement design is based on the TA method used in Japan.

Target pavement thickness is calculated using formula (1.1) based on the Cumulative number of wheels equivalent loads to 5 tons during the design period (N) and the CBR of the subgrade.

$TA = 3.84\ N^{0.16} / CBR^{0.3}$ (formula 1.1)

TA : Total pavement thickness converted into an equivalent thickness of hot mix asphalt concrete (cm)

N : Cumulative number of wheels equivalent loads to 5 tons during the design period

CBR : Subgrade CBR (%)

$N = \sum_{i=1}^{n} (N(5\text{ tons}) \times 365 \times ai)$ (formula 1.2)

N : Cumulative number of wheels equivalent loads to 5 tons during the design period

N(5 tons) : Number of equivalent wheel loads of each vehicle/ day

$N(5\text{ tons}) = (\text{Wheel loads}/5)^4 \times \text{Number of wheels}$

n : Design Period (normally 10 years)

ai: Traffic Growth Ratio

2 Target Total Pavement Thickness (TA)

2.1 Design Condition

Traffic Volume	200	Vehicles/day	Light Vehicle	190	Vehicles/day	95 %
			Heavy Vehicle	10	Vehicles/day	5 %
Design Period	10	years				
Traffic Growth Ratio	3	%				
Subgrade CBR	6	%				

2.2 Light Vehicle N (5 tons) 2- ton Passenger Car or Light Truck

0.5 ton	0.5 ton
0.5 ton	0.5 ton

Light Vehicle N (5 tons) = $4 \times (0.5/5)^4$

= 0.0004

2.3 Heavy Vehicle N (5 tons) 10- ton Heavy Truck

1.0 ton	4.0 ton
1.0 ton	4.0 ton

Heavy Vehicle N (5 tons) = $2 \times (1.0/5)^4 + 2 \times (4.0/5)^4$

= 0.823

2.4 Cumulative number of wheels equivalent loads to 5 tons during the design period（N）

$$N = \sum_{i=1}^{10} \left(190 \times 0.0004 + 10 \times 0.823 \right) \times 365 \times \left(1.03 \right)^{i}$$

$$= 34{,}755$$

2.5 Calculation of TA

$$TA = 3.84 \times \left(34{,}755 \right)^{0.16} / \left(6 \right)^{0.3}$$

$$= 12.0$$

3 Conversion Coefficient

Table 3.1 shows conversion coefficient of pavement structure.

Table 3.1 Conversion Coefficient of pavement Structure.

Pavement Structure		Conversion Coefficient
Asphalt Surface Course		1.00
Base Course	(M-30)	0.35
Bab-base Course	(C-40)	0.25

4 Pavement Structure

4.1 Design Pavement Structure

The pavement three layers: asphalt surface, base course, and sub-base course. Table 4.1 shows minimum thickness of each layer. TA' obtained by multiplying the thickness of each layer by the conversion coefficient shall be set to be equal to or greater than TA.

$TA' = a1T1 + a2T2 + a3T3$ （Formula 4.1）

$TA' \geqq TA$

Table 4.1 Minimum Thickness Each Pavement Structure

Pavement Structure		Minimum Thickness
Asphalt Surface Course		5cm
Base Course	(M-30)	10cm
Bab-base Course	(C-40)	12cm

Note: minimum thickness is 3 times of stone size

4.2 Design of Pavement Thickness

Table 4.2 shows the design pavement thickness (cm) of the three layers of the asphalt surface, base course, and sub-base course.

Table 4.2 Design of Pavement Structure

Pavement Structure		Pavement Thickness
Asphalt Surface Course		5 cm
Base Course	(M-30)	10 cm
Bab-base Course	(C-40)	15 cm

$TA' = 5 \times 1.0 + 10 \times 0.35 + 15 \times 0.25$

$12.3 \geqq TA = 12.0$

$TA' \geqq TA$

Since TA' exceeds TA, the layer thickness in Table 4.2 is used as the design pavement thickness.

N: Cumulative number of wheels equivalent loads to 5 tons during 10 years

1	(	0.0004	x	190	+	0.823	x	10	)	x 365					3,032
2	(	0.0004	x	190	+	0.823	x	10	)	x 365	x	(	1.03	)	3,123
3	(	0.0004	x	190	+	0.823	x	10	)	x 365	x	(	1.03	$)^2$	3,216
4	(	0.0004	x	190	+	0.823	x	10	)	x 365	x	(	1.03	$)^3$	3,313
5	(	0.0004	x	190	+	0.823	x	10	)	x 365	x	(	1.03	$)^4$	3,412
6	(	0.0004	x	190	+	0.823	x	10	)	x 365	x	(	1.03	$)^5$	3,515
7	(	0.0004	x	190	+	0.823	x	10	)	x 365	x	(	1.03	$)^6$	3,620
8	(	0.0004	x	190	+	0.823	x	10	)	x 365	x	(	1.03	$)^7$	3,729
9	(	0.0004	x	190	+	0.823	x	10	)	x 365	x	(	1.03	$)^8$	3,840
10	(	0.0004	x	190	+	0.823	x	10	)	x 365	x	(	1.03	$)^9$	3,956

N = 34,755

Traffic Volume: 300 vehicles per day, Design CBR: 4%

1 Pavement Structure Design

1.1 Target pavement thickness

The pavement design is based on the TA method used in Japan.

Target pavement thickness is calculated using formula (1.1) based on the Cumulative number of wheels equivalent loads to 5 tons during the design period (N) and the CBR of the subgrade.

$TA=3.84\ N^{0.16} / CBR^{0.3}$ (formula 1.1)

TA : Total pavement thickness converted into an equivalent thickness of hot mix asphalt concrete (cm)

N : Cumulative number of wheels equivalent loads to 5 tons during the design period

CBR : Subgrade CBR (%)

$N = \sum_{i=1}^{n} (N(5\ tons) \times 365 \times ai)$ (formula 1.2)

N : Cumulative number of wheels equivalent loads to 5 tons during the design period

N(5 tons) : Number of equivalent wheel loads of each vehicle/ day

$N(5\ tons)=(Wheel\ loads/5)^4 \times$ Number of wheels

n : Design Period (normally 10 years)

ai: Traffic Growth Ratio

2 Target Total Pavement Thickness (TA)

2.1 Design Condition

Traffic Volume	300	Vehicles/day	Light Vehicle	285	Vehicles/day	95 %
			Heavy Vehicle	15	Vehicles/day	5 %
Design Period	10	years				
Traffic Growth Ratio	3	%				
Subgrade CBR	4	%				

2.2 Light Vehicle N (5 tons) 2- ton Passenger Car or Light Truck

0.5 ton	0.5 ton
0.5 ton	0.5 ton

Light Vehicle N (5 tons) = $4 \times (0.5/5)^4$

= 0.0004

2.3 Heavy Vehicle N (5 tons) 10- ton Heavy Truck

1.0 ton	4.0 ton
1.0 ton	4.0 ton

Heavy Vehicle N (5 tons) = $2 \times (1.0/5)^4 + 2 \times (4.0/5)^4$

= 0.823

2.4 Cumulative number of wheels equivalent loads to 5 tons during the design period（N）

$$N = \sum_{i=1}^{10} \left(285 \times 0.0004 + 15 \times 0.823 \right) \times 365 \times (1.03)^{i}$$

$$= 52{,}132$$

2.5 Calculation of TA

$$TA = 3.84 \times (52{,}132)^{0.16} / (4)^{0.3}$$

$$= 14.4$$

3 Conversion Coefficient

Table 3.1 shows conversion coefficient of pavement structure.

Table 3.1 Conversion Coefficient of pavement Structure.

Pavement Structure		Conversion Coefficient
Asphalt Surface Course		1.00
Base Course	(M-30)	0.35
Bab-base Course	(C-40)	0.25

4 Pavement Structure

4.1 Design Pavement Structure

The pavement three layers: asphalt surface, base course, and sub-base course. Table 4.1 shows minimum thickness of each layer. TA' obtained by multiplying the thickness of each layer by the conversion coefficient shall be set to be equal to or greater than TA.

$TA' = a1T1 + a2T2 + a3T3$ （Formula 4.1）

$TA' \geqq TA$

Table 4.1 Minimum Thickness Each Pavement Structure

Pavement Structure		Minimum Thickness
Asphalt Surface Course		5cm
Base Course	(M-30)	10cm
Bab-base Course	(C-40)	12cm

Note: minimum thickness is 3 times of stone size

4.2 Design of Pavement Thickness

Table 4.2 shows the design pavement thickness (cm) of the three layers of the asphalt surface, base course, and sub-base course.

Table 4.2 Design of Pavement Structure

Pavement Structure		Pavement Thickness
Asphalt Surface Course		5 cm
Base Course	(M-30)	15 cm
Bab-base Course	(C-40)	20 cm

$TA' = 5 \times 1.0 + 15 \times 0.35 + 20 \times 0.25$

$15.3 \geqq TA = 14.4$

$TA' \geqq TA$

Since TA' exceeds TA, the layer thickness in Table 4.2 is used as the design pavement thickness.

N: Cumulative number of wheels equivalent loads to 5 tons during 10 years

1	(	0.0004	x	285	+	0.823	x	15	)	x 365				4,548
2	(	0.0004	x	285	+	0.823	x	15	)	x 365	x	(1.03)		4,684
3	(	0.0004	x	285	+	0.823	x	15	)	x 365	x	(1.03)^{2}		4,824
4	(	0.0004	x	285	+	0.823	x	15	)	x 365	x	(1.03)^{3}		4,969
5	(	0.0004	x	285	+	0.823	x	15	)	x 365	x	(1.03)^{4}		5,118
6	(	0.0004	x	285	+	0.823	x	15	)	x 365	x	(1.03)^{5}		5,272
7	(	0.0004	x	285	+	0.823	x	15	)	x 365	x	(1.03)^{6}		5,430
8	(	0.0004	x	285	+	0.823	x	15	)	x 365	x	(1.03)^{7}		5,593
9	(	0.0004	x	285	+	0.823	x	15	)	x 365	x	(1.03)^{8}		5,761
10	(	0.0004	x	285	+	0.823	x	15	)	x 365	x	(1.03)^{9}		5,934
													N =	52,132

Traffic Volume: 300 vehicles per day, Design CBR: 6%

1 Pavement Structure Design

1.1 Target pavement thickness

The pavement design is based on the TA method used in Japan.

Target pavement thickness is calculated using formula (1.1) based on the Cumulative number of wheels equivalent loads to 5 tons during the design period (N) and the CBR of the subgrade.

$TA=3.84\ N^{0.16} / CBR^{0.3}$ (formula 1.1)

TA : Total pavement thickness converted into an equivalent thickness of hot mix asphalt concrete (cm)

N : Cumulative number of wheels equivalent loads to 5 tons during the design period

CBR : Subgrade CBR (%)

$N = \sum_{i=1}^{n} (N(5\ tons) \times 365 \times ai)$ (formula 1.2)

N : Cumulative number of wheels equivalent loads to 5 tons during the design period

N(5 tons) : Number of equivalent wheel loads of each vehicle/ day

$N(5\ tons)=(Wheel\ loads/5)^4$ x Number of wheels

n : Design Period (normally 10 years)

ai: Traffic Growth Ratio

2 Target Total Pavement Thickness (TA)

2.1 Design Condition

Traffic Volume	300	Vehicles/day	Light Vehicle	285	Vehicles/day	95 %
			Heavy Vehicle	15	Vehicles/day	5 %
Design Period	10	years				
Traffic Growth Ratio	3	%				
Subgrade CBR	6	%				

2.2 Light Vehicle N (5 tons) 2- ton Passenger Car or Light Truck

0.5 ton	0.5 ton
0.5 ton	0.5 ton

Light Vehicle N (5 tons) = $4 \times (0.5/5)^4$

= 0.0004

2.3 Heavy Vehicle N (5 tons) 10- ton Heavy Truck

1.0 ton	4.0 ton
1.0 ton	4.0 ton

Heavy Vehicle N (5 tons) = $2 \times (1.0/5)^4 + 2 \times (4.0/5)^4$

= 0.823

2.4 Cumulative number of wheels equivalent loads to 5 tons during the design period（N）

$$N = \sum_{i=1}^{10} \left(285 \times 0.0004 + 15 \times 0.823 \right) \times 365 \times \left(1.03 \right)^{i}$$

$$= 52{,}132$$

2.5 Calculation of TA

$$TA = 3.84 \times \left(52{,}132 \right)^{0.16} / \left(6 \right)^{0.3}$$

$$= 12.8$$

3 Conversion Coefficient

Table 3.1 shows conversion coefficient of pavement structure.

Table 3.1 Conversion Coefficient of pavement Structure.

Pavement Structure		Conversion Coefficient
Asphalt Surface Course		1.00
Base Course	(M-30)	0.35
Bab-base Course	(C-40)	0.25

4 Pavement Structure

4.1 Design Pavement Structure

The pavement three layers: asphalt surface, base course, and sub-base course. Table 4.1 shows minimum thickness of each layer. TA' obtained by multiplying the thickness of each layer by the conversion coefficient shall be set to be equal to or greater than TA.

$TA' = a1T1 + a2T2 + a3T3$ （Formula 4.1）

$TA' \geqq TA$

Table 4.1 Minimum Thickness Each Pavement Structure

Pavement Structure		Minimum Thickness
Asphalt Surface Course		5cm
Base Course	(M-30)	10cm
Bab-base Course	(C-40)	12cm

Note: minimum thickness is 3 times of stone size

4.2 Design of Pavement Thickness

Table 4.2 shows the design pavement thickness (cm) of the three layers of the asphalt surface, base course, and sub-base course.

Table 4.2 Design of Pavement Structure

Pavement Structure		Pavement Thickness
Asphalt Surface Course		5 cm
Base Course	(M-30)	10 cm
Bab-base Course	(C-40)	20 cm

$TA' = 5 \times 1.0 + 10 \times 0.35 + 20 \times 0.25$

$13.5 \geqq TA = 12.8$

$TA' \geqq TA$

Since TA' exceeds TA, the layer thickness in Table 4.2 is used as the design pavement thickness.

N: Cumulative number of wheels equivalent loads to 5 tons during 10 years

1	(	0.0004	x	285	+	0.823	x	15	)	x 365				4,548
2	(	0.0004	x	285	+	0.823	x	15	)	x 365	x	(1.03)		4,684
3	(	0.0004	x	285	+	0.823	x	15	)	x 365	x	(1.03)^{2}		4,824
4	(	0.0004	x	285	+	0.823	x	15	)	x 365	x	(1.03)^{3}		4,969
5	(	0.0004	x	285	+	0.823	x	15	)	x 365	x	(1.03)^{4}		5,118
6	(	0.0004	x	285	+	0.823	x	15	)	x 365	x	(1.03)^{5}		5,272
7	(	0.0004	x	285	+	0.823	x	15	)	x 365	x	(1.03)^{6}		5,430
8	(	0.0004	x	285	+	0.823	x	15	)	x 365	x	(1.03)^{7}		5,593
9	(	0.0004	x	285	+	0.823	x	15	)	x 365	x	(1.03)^{8}		5,761
10	(	0.0004	x	285	+	0.823	x	15	)	x 365	x	(1.03)^{9}		5,934
													N =	52,132

Traffic Volume: 300 vehicles per day, Design CBR: 8%

1 Pavement Structure Design

1.1 Target pavement thickness

The pavement design is based on the TA method used in Japan.

Target pavement thickness is calculated using formula (1.1) based on the Cumulative number of wheels equivalent loads to 5 tons during the design period (N) and the CBR of the subgrade.

$TA=3.84\ N^{0.16} / CBR^{0.3}$ (formula 1.1)

TA : Total pavement thickness converted into an equivalent thickness of hot mix asphalt concrete (cm)

N : Cumulative number of wheels equivalent loads to 5 tons during the design period

CBR : Subgrade CBR (%)

$N = \sum_{i=1}^{n} (N(5\ tons) \times 365 \times ai)$ (formula 1.2)

N : Cumulative number of wheels equivalent loads to 5 tons during the design period

N(5 tons) : Number of equivalent wheel loads of each vehicle/ day

$N(5\ tons)=(Wheel\ loads/5)^4$ x Number of wheels

n : Design Period (normally 10 years)

ai: Traffic Growth Ratio

2 Target Total Pavement Thickness (TA)

2.1 Design Condition

Traffic Volume	300	Vehicles/day	Light Vehicle	285	Vehicles/day	95 %
			Heavy Vehicle	15	Vehicles/day	5 %
Design Period	10	years				
Traffic Growth Ratio	3	%				
Subgrade CBR	8	%				

2.2 Light Vehicle N (5 tons) 2- ton Passenger Car or Light Truck

0.5 ton	0.5 ton
0.5 ton	0.5 ton

Light Vehicle N (5 tons) = $4 \times (0.5/5)^4$

= 0.0004

2.3 Heavy Vehicle N (5 tons) 10- ton Heavy Truck

1.0 ton	4.0 ton
1.0 ton	4.0 ton

Heavy Vehicle N (5 tons) = $2 \times (1.0/5)^4 + 2 \times (4.0/5)^4$

= 0.823

2.4 Cumulative number of wheels equivalent loads to 5 tons during the design period（N）

$$N = \sum_{i=1}^{10} (285 \times 0.0004 + 15 \times 0.823) \times 365 \times (1.03)^{i}$$

$$= 52{,}132$$

2.5 Calculation of TA

$$TA = 3.84 \times (\quad = \quad)^{0.16} / (8)^{0.3}$$

$$= 11.7$$

3 Conversion Coefficient

Table 3.1 shows conversion coefficient of pavement structure.

Table 3.1 Conversion Coefficient of pavement Structure.

Pavement Structure		Conversion Coefficient
Asphalt Surface Course		1.00
Base Course	(M-30)	0.35
Bab-base Course	(C-40)	0.25

4 Pavement Structure

4.1 Design Pavement Structure

The pavement three layers: asphalt surface, base course, and sub-base course. Table 4.1 shows minimum thickness of each layer. TA' obtained by multiplying the thickness of each layer by the conversion coefficient shall be set to be equal to or greater than TA.

TA'=a1T1 + a2T2 + a3T3 (Formula 4.1)

TA'≧TA

Table 4.1 Minimum Thickness Each Pavement Structure

Pavement Structure		Minimum Thickness
Asphalt Surface Course		5cm
Base Course	(M-30)	10cm
Bab-base Course	(C-40)	12cm

Note: minimum thickness is 3 times of stone size

4.2 Design of Pavement Thickness

Table 4.2 shows the design pavement thickness (cm) of the three layers of the asphalt surface, base course, and sub-base course.

Table 4.2 Design of Pavement Structure

Pavement Structure		Pavement Thickness
Asphalt Surface Course		5 cm
Base Course	(M-30)	10 cm
Bab-base Course	(C-40)	15 cm

TA'= 5 x1.0+ 10 x0.35+ 15 x0.25

12.3 ≧TA= 11.7

TA'≧TA

Since TA' exceeds TA, the layer thickness in Table 4.2 is used as the design pavement thickness.

N: Cumulative number of wheels equivalent loads to 5 tons during 10 years

1	(	0.0004	x	285	+	0.823	x	15	)	x 365				4,548
2	(	0.0004	x	285	+	0.823	x	15	)	x 365	x	(1.03)		4,684
3	(	0.0004	x	285	+	0.823	x	15	)	x 365	x	(1.03)^{2}		4,824
4	(	0.0004	x	285	+	0.823	x	15	)	x 365	x	(1.03)^{3}		4,969
5	(	0.0004	x	285	+	0.823	x	15	)	x 365	x	(1.03)^{4}		5,118
6	(	0.0004	x	285	+	0.823	x	15	)	x 365	x	(1.03)^{5}		5,272
7	(	0.0004	x	285	+	0.823	x	15	)	x 365	x	(1.03)^{6}		5,430
8	(	0.0004	x	285	+	0.823	x	15	)	x 365	x	(1.03)^{7}		5,593
9	(	0.0004	x	285	+	0.823	x	15	)	x 365	x	(1.03)^{8}		5,761
10	(	0.0004	x	285	+	0.823	x	15	)	x 365	x	(1.03)^{9}		5,934
													N =	52,132

Traffic Volume: 500 vehicles per day, Design CBR: 4%

1 Pavement Structure Design

1.1 Target pavement thickness

The pavement design is based on the TA method used in Japan.

Target pavement thickness is calculated using formula (1.1) based on the Cumulative number of wheels equivalent loads to 5 tons during the design period (N) and the CBR of the subgrade.

$TA=3.84\ N^{0.16} / CBR^{0.3}$ (formula 1.1)

TA : Total pavement thickness converted into an equivalent thickness of hot mix asphalt concrete (cm)

N : Cumulative number of wheels equivalent loads to 5 tons during the design period

CBR : Subgrade CBR (%)

$N = \sum_{i=1}^{n} (N(5\ tons) \times 365 \times ai)$ (formula 1.2)

N : Cumulative number of wheels equivalent loads to 5 tons during the design period

N(5 tons) : Number of equivalent wheel loads of each vehicle/ day

$N(5\ tons)=(Wheel\ loads/5)^4 \times Number\ of\ wheels$

n : Design Period (normally 10 years)

ai: Traffic Growth Ratio

2 Target Total Pavement Thickness (TA)

2.1 Design Condition

Traffic Volume	500	Vehicles/day	Light Vehicle	475	Vehicles/day	95 %
			Heavy Vehicle	25	Vehicles/day	5 %
Design Period	10	years				
Traffic Growth Ratio	3	%				
Subgrade CBR	4	%				

2.2 Light Vehicle N (5 tons) 2- ton Passenger Car or Light Truck

0.5 ton	0.5 ton
0.5 ton	0.5 ton

Light Vehicle N (5 tons) = $4 \times (0.5/5)^4$

= 0.0004

2.3 Heavy Vehicle N (5 tons) 10- ton Heavy Truck

1.0 ton	4.0 ton
1.0 ton	4.0 ton

Heavy Vehicle N (5 tons) = $2 \times (1.0/5)^4 + 2 \times (4.0/5)^4$

= 0.823

2.4 Cumulative number of wheels equivalent loads to 5 tons during the design period（N）

$$N = \sum_{i=1}^{10} \left(475 \times 0.0004 + 25 \times 0.823 \right) \times 365 \times (1.03)^{i}$$

$$= 86{,}887$$

2.5 Calculation of TA

$$TA = 3.84 \times (86{,}887)^{0.16} / (4)^{0.3}$$

$$= 15.6$$

3 Conversion Coefficient

Table 3.1 shows conversion coefficient of pavement structure.

Table 3.1 Conversion Coefficient of pavement Structure.

Pavement Structure		Conversion Coefficient
Asphalt Surface Course		1.00
Base Course	(M-30)	0.35
Bab-base Course	(C-40)	0.25

4 Pavement Structure

4.1 Design Pavement Structure

The pavement three layers: asphalt surface, base course, and sub-base course. Table 4.1 shows minimum thickness of each layer. TA' obtained by multiplying the thickness of each layer by the conversion coefficient shall be set to be equal to or greater than TA.

$TA' = a1T1 + a2T2 + a3T3$ （Formula 4.1）

$TA' \geqq TA$

Table 4.1 Minimum Thickness Each Pavement Structure

Pavement Structure		Minimum Thickness
Asphalt Surface Course		5cm
Base Course	(M-30)	10cm
Bab-base Course	(C-40)	12cm

Note: minimum thickness is 3 times of stone size

4.2 Design of Pavement Thickness

Table 4.2 shows the design pavement thickness (cm) of the three layers of the asphalt surface, base course, and sub-base course.

Table 4.2 Design of Pavement Structure

Pavement Structure		Pavement Thickness
Asphalt Surface Course		5 cm
Base Course	(M-30)	15 cm
Bab-base Course	(C-40)	25 cm

$TA' = 5 \times 1.0 + 15 \times 0.35 + 25 \times 0.25$

$16.5 \geqq TA = 15.6$

$TA' \geqq TA$

Since TA' exceeds TA, the layer thickness in Table 4.2 is used as the design pavement thickness.

N: Cumulative number of wheels equivalent loads to 5 tons during 10 years

1	(	0.0004	x	475	+	0.823	x	25	)	x 365					7,579
2	(	0.0004	x	475	+	0.823	x	25	)	x 365	x	(	1.03	)	7,807
3	(	0.0004	x	475	+	0.823	x	25	)	x 365	x	(	1.03	$)^2$	8,041
4	(	0.0004	x	475	+	0.823	x	25	)	x 365	x	(	1.03	$)^3$	8,282
5	(	0.0004	x	475	+	0.823	x	25	)	x 365	x	(	1.03	$)^4$	8,530
6	(	0.0004	x	475	+	0.823	x	25	)	x 365	x	(	1.03	$)^5$	8,786
7	(	0.0004	x	475	+	0.823	x	25	)	x 365	x	(	1.03	$)^6$	9,050
8	(	0.0004	x	475	+	0.823	x	25	)	x 365	x	(	1.03	$)^7$	9,321
9	(	0.0004	x	475	+	0.823	x	25	)	x 365	x	(	1.03	$)^8$	9,601
10	(	0.0004	x	475	+	0.823	x	25	)	x 365	x	(	1.03	$)^9$	9,889

N = 86,887

Traffic Volume: 500 vehicles per day, Design CBR: 6%

1 Pavement Structure Design

1.1 Target pavement thickness

The pavement design is based on the TA method used in Japan.

Target pavement thickness is calculated using formula (1.1) based on the Cumulative number of wheels equivalent loads to 5 tons during the design period (N) and the CBR of the subgrade.

$TA = 3.84\ N^{0.16} / CBR^{0.3}$ (formula 1.1)

TA : Total pavement thickness converted into an equivalent thickness of hot mix asphalt concrete (cm)

N : Cumulative number of wheels equivalent loads to 5 tons during the design period

CBR : Subgrade CBR (%)

$N = \sum_{i=1}^{n} (N(5\ tons) \times 365 \times ai)$ (formula 1.2)

N : Cumulative number of wheels equivalent loads to 5 tons during the design period

N(5 tons) : Number of equivalent wheel loads of each vehicle/ day

$N(5\ tons) = (Wheel\ loads/5)^4 \times$ Number of wheels

n : Design Period (normally 10 years)

ai: Traffic Growth Ratio

2 Target Total Pavement Thickness (TA)

2.1 Design Condition

Traffic Volume	500	Vehicles/day	Light Vehicle	475	Vehicles/day	95 %
			Heavy Vehicle	25	Vehicles/day	5 %
Design Period	10	years				
Traffic Growth Ratio	3	%				
Subgrade CBR	6	%				

2.2 Light Vehicle N (5 tons) 2- ton Passenger Car or Light Truck

0.5 ton	0.5 ton
0.5 ton	0.5 ton

Light Vehicle N (5 tons) $= 4 \times (0.5/5)^4$

$= 0.0004$

2.3 Heavy Vehicle N (5 tons) 10- ton Heavy Truck

1.0 ton	4.0 ton
1.0 ton	4.0 ton

Heavy Vehicle N (5 tons) $= 2 \times (1.0/5)^4 + 2 \times (4.0/5)^4$

$= 0.823$

2.4 Cumulative number of wheels equivalent loads to 5 tons during the design period（N）

$$N = \sum_{i=1}^{10} \left(475 \times 0.0004 + 25 \times 0.823 \right) \times 365 \times (1.03)^{i}$$

$$= 86{,}887$$

2.5 Calculation of TA

$$TA = 3.84 \times \left(86{,}887 \right)^{0.16} / \left(6 \right)^{0.3}$$

$$= 13.8$$

3 Conversion Coefficient

Table 3.1 shows conversion coefficient of pavement structure.

Table 3.1 Conversion Coefficient of pavement Structure.

Pavement Structure		Conversion Coefficient
Asphalt Surface Course		1.00
Base Course	(M-30)	0.35
Bab-base Course	(C-40)	0.25

4 Pavement Structure

4.1 Design Pavement Structure

The pavement three layers: asphalt surface, base course, and sub-base course. Table 4.1 shows minimum thickness of each layer. TA' obtained by multiplying the thickness of each layer by the conversion coefficient shall be set to be equal to or greater than TA.

$TA' = a1T1 + a2T2 + a3T3$ （Formula 4.1）

$TA' \geqq TA$

Table 4.1 Minimum Thickness Each Pavement Structure

Pavement Structure		Minimum Thickness
Asphalt Surface Course		5cm
Base Course	(M-30)	10cm
Bab-base Course	(C-40)	12cm

Note: minimum thickness is 3 times of stone size

4.2 Design of Pavement Thickness

Table 4.2 shows the design pavement thickness (cm) of the three layers of the asphalt surface, base course, and sub-base course.

Table 4.2 Design of Pavement Structure

Pavement Structure		Pavement Thickness
Asphalt Surface Course		5 cm
Base Course	(M-30)	15 cm
Bab-base Course	(C-40)	20 cm

$TA' = 5 \times 1.0 + 15 \times 0.35 + 20 \times 0.25$

$15.3 \geqq TA = 13.8$

$TA' \geqq TA$

Since TA' exceeds TA, the layer thickness in Table 4.2 is used as the design pavement thickness.

N: Cumulative number of wheels equivalent loads to 5 tons during 10 years

1	(	0.0004	x	475	+	0.823	x	25	)	x 365					7,579
2	(	0.0004	x	475	+	0.823	x	25	)	x 365	x	(	1.03	)	7,807
3	(	0.0004	x	475	+	0.823	x	25	)	x 365	x	(	1.03	$)^2$	8,041
4	(	0.0004	x	475	+	0.823	x	25	)	x 365	x	(	1.03	$)^3$	8,282
5	(	0.0004	x	475	+	0.823	x	25	)	x 365	x	(	1.03	$)^4$	8,530
6	(	0.0004	x	475	+	0.823	x	25	)	x 365	x	(	1.03	$)^5$	8,786
7	(	0.0004	x	475	+	0.823	x	25	)	x 365	x	(	1.03	$)^6$	9,050
8	(	0.0004	x	475	+	0.823	x	25	)	x 365	x	(	1.03	$)^7$	9,321
9	(	0.0004	x	475	+	0.823	x	25	)	x 365	x	(	1.03	$)^8$	9,601
10	(	0.0004	x	475	+	0.823	x	25	)	x 365	x	(	1.03	$)^9$	9,889

N = 86,887

Traffic Volume: 500 vehicles per day, Design CBR: 8%

1 Pavement Structure Design

1.1 Target pavement thickness

The pavement design is based on the TA method used in Japan.

Target pavement thickness is calculated using formula (1.1) based on the Cumulative number of wheels equivalent loads to 5 tons during the design period (N) and the CBR of the subgrade.

$TA=3.84\ N^{0.16} / CBR^{0.3}$ (formula 1.1)

TA : Total pavement thickness converted into an equivalent thickness of hot mix asphalt concrete (cm)

N : Cumulative number of wheels equivalent loads to 5 tons during the design period

CBR : Subgrade CBR (%)

$N = \sum_{i=1}^{n} (N(5\ tons) \times 365 \times ai)$ (formula 1.2)

N : Cumulative number of wheels equivalent loads to 5 tons during the design period

N(5 tons) : Number of equivalent wheel loads of each vehicle/ day

$N(5\ tons)=(Wheel\ loads/5)^4$ x Number of wheels

n : Design Period (normally 10 years)

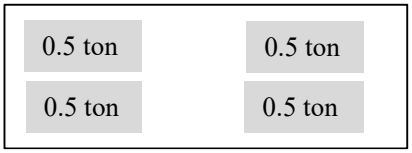
ai: Traffic Growth Ratio

2 Target Total Pavement Thickness (TA)

2.1 Design Condition

Traffic Volume	500	Vehicles/day	Light Vehicle	475	Vehicles/day	95 %
			Heavy Vehicle	25	Vehicles/day	5 %
Design Period	10	years				
Traffic Growth Ratio	3	%				
Subgrade CBR	8	%				

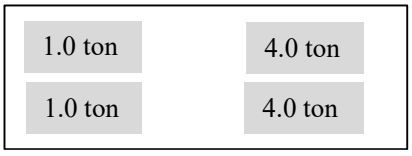
2.2 Light Vehicle N (5 tons) 2- ton Passenger Car or Light Truck



Light Vehicle N (5 tons) = $4 \times (0.5/5)^4$

= 0.0004

2.3 Heavy Vehicle N (5 tons) 10- ton Heavy Truck



Heavy Vehicle N (5 tons) = $2 \times (1.0/5)^4 + 2 \times (4.0/5)^4$

= 0.823

2.4 Cumulative number of wheels equivalent loads to 5 tons during the design period（N）

$$N = \sum_{i=1}^{10} \left(475 \times 0.0004 + 25 \times 0.823 \right) \times 365 \times (1.03)^{i}$$

$$= 86{,}887$$

2.5 Calculation of TA

$$TA = 3.84 \times \left(86{,}887 \right)^{0.16} / \left(8 \right)^{0.3}$$

$$= 12.7$$

3 Conversion Coefficient

Table 3.1 shows conversion coefficient of pavement structure.

Table 3.1 Conversion Coefficient of pavement Structure.

Pavement Structure		Conversion Coefficient
Asphalt Surface Course		1.00
Base Course	(M-30)	0.35
Bab-base Course	(C-40)	0.25

4 Pavement Structure

4.1 Design Pavement Structure

The pavement three layers: asphalt surface, base course, and sub-base course. Table 4.1 shows minimum thickness of each layer. TA' obtained by multiplying the thickness of each layer by the conversion coefficient shall be set to be equal to or greater than TA.

$TA' = a1T1 + a2T2 + a3T3$ （Formula 4.1）

$TA' \geqq TA$

Table 4.1 Minimum Thickness Each Pavement Structure

Pavement Structure		Minimum Thickness
Asphalt Surface Course		5cm
Base Course	(M-30)	10cm
Bab-base Course	(C-40)	12cm

Note: minimum thickness is 3 times of stone size

4.2 Design of Pavement Thickness

Table 4.2 shows the design pavement thickness (cm) of the three layers of the asphalt surface, base course, and sub-base course.

Table 4.2 Design of Pavement Structure

Pavement Structure		Pavement Thickness
Asphalt Surface Course		5 cm
Base Course	(M-30)	10 cm
Bab-base Course	(C-40)	20 cm

$TA' = 5 \times 1.0 + 10 \times 0.35 + 20 \times 0.25$

$13.5 \geqq TA = 12.7$

Since TA' exceeds TA, the layer thickness in Table 4.2 is used as the design pavement thickness.

N: Cumulative number of wheels equivalent loads to 5 tons during 10 years

1	(	0.0004	x	475	+	0.823	x	25	)	x 365					7,579
2	(	0.0004	x	475	+	0.823	x	25	)	x 365	x	(	1.03	)	7,807
3	(	0.0004	x	475	+	0.823	x	25	)	x 365	x	(	1.03	$)^2$	8,041
4	(	0.0004	x	475	+	0.823	x	25	)	x 365	x	(	1.03	$)^3$	8,282
5	(	0.0004	x	475	+	0.823	x	25	)	x 365	x	(	1.03	$)^4$	8,530
6	(	0.0004	x	475	+	0.823	x	25	)	x 365	x	(	1.03	$)^5$	8,786
7	(	0.0004	x	475	+	0.823	x	25	)	x 365	x	(	1.03	$)^6$	9,050
8	(	0.0004	x	475	+	0.823	x	25	)	x 365	x	(	1.03	$)^7$	9,321
9	(	0.0004	x	475	+	0.823	x	25	)	x 365	x	(	1.03	$)^8$	9,601
10	(	0.0004	x	475	+	0.823	x	25	)	x 365	x	(	1.03	$)^9$	9,889

N = 86,887

Traffic Volume: 1,000 vehicles per day, Design CBR: 4%

1 Pavement Structure Design

1.1 Target pavement thickness

The pavement design is based on the TA method used in Japan.

Target pavement thickness is calculated using formula (1.1) based on the Cumulative number of wheels equivalent loads to 5 tons during the design period (N) and the CBR of the subgrade.

$TA=3.84\ N^{0.16} / CBR^{0.3}$ (formula 1.1)

TA : Total pavement thickness converted into an equivalent thickness of hot mix asphalt concrete (cm)

N : Cumulative number of wheels equivalent loads to 5 tons during the design period

CBR : Subgrade CBR (%)

$N=\sum_{i=1}^{n}(N(5\text{ tons}) \times 365 \times ai)$ (formula 1.2)

N : Cumulative number of wheels equivalent loads to 5 tons during the design period

N(5 tons) : Number of equivalent wheel loads of each vehicle/ day

$N(5\text{ tons})=(\text{Wheel loads}/5)^4 \times \text{Number of wheels}$

n : Design Period (normally 10 years)

ai: Traffic Growth Ratio

2 Target Total Pavement Thickness (TA)

2.1 Design Condition

Traffic Volume	1000 Vehicles/day	Light Vehicle	950 Vehicles/day	95 %
		Heavy Vehicle	50 Vehicles/day	5 %
Design Period	10 years			
Traffic Growth Ratio	3 %			
Subgrade CBR	4 %			

2.2 Light Vehicle N (5 tons) 2- ton Passenger Car or Light Truck

0.5 ton	0.5 ton
0.5 ton	0.5 ton

Light Vehicle N (5 tons) $= 4 \times (0.5/5)^4$

$= 0.0004$

2.3 Heavy Vehicle N (5 tons) 10- ton Heavy Truck

1.0 ton	4.0 ton
1.0 ton	4.0 ton

Heavy Vehicle N (5 tons) $= 2 \times (1.0/5)^4 + 2 \times (4.0/5)^4$

$= 0.823$

2.4 Cumulative number of wheels equivalent loads to 5 tons during the design period（N）

$$N = \sum_{i=1}^{10} \left(950 \times 0.0004 + 50 \times 0.823 \right) \times 365 \times (1.03)^{i}$$

$$= 173{,}775$$

2.5 Calculation of TA

$$TA = 3.84 \times \left(173{,}775 \right)^{0.16} / \left(4 \right)^{0.3}$$

$$= 17.5$$

3 Conversion Coefficient

Table 3.1 shows conversion coefficient of pavement structure.

Table 3.1 Conversion Coefficient of pavement Structure.

Pavement Structure		Conversion Coefficient
Asphalt Surface Course		1.00
Base Course	(M-30)	0.35
Bab-base Course	(C-40)	0.25

4 Pavement Structure

4.1 Design Pavement Structure

The pavement three layers: asphalt surface, base course, and sub-base course. Table 4.1 shows minimum thickness of each layer. TA' obtained by multiplying the thickness of each layer by the conversion coefficient shall be set to be equal to or greater than TA.

$TA' = a1T1 + a2T2 + a3T3$ （Formula 4.1）

$TA' \geqq TA$

Table 4.1 Minimum Thickness Each Pavement Structure

Pavement Structure		Minimum Thickness
Asphalt Surface Course		5cm
Base Course	(M-30)	10cm
Bab-base Course	(C-40)	12cm

Note: minimum thickness is 3 times of stone size

4.2 Design of Pavement Thickness

Table 4.2 shows the design pavement thickness (cm) of the three layers of the asphalt surface, base course, and sub-base course.

Table 4.2 Design of Pavement Structure

Pavement Structure		Pavement Thickness
Asphalt Surface Course		5 cm
Base Course	(M-30)	15 cm
Bab-base Course	(C-40)	25 cm

$TA' = 5 \times 1.0 + 15 \times 0.35 + 25 \times 0.25$

$16.5 \geqq TA = 17.5$

Since TA' exceeds TA, the layer thickness in Table 4.2 is used as the design pavement thickness.

N: Cumulative number of wheels equivalent loads to 5 tons during 10 years

1	(	0.0004	x	950	+	0.823	x	50	)	x 365					15,158
2	(	0.0004	x	950	+	0.823	x	50	)	x 365	x	(	1.03	)	15,613
3	(	0.0004	x	950	+	0.823	x	50	)	x 365	x	(	1.03	$)^2$	16,082
4	(	0.0004	x	950	+	0.823	x	50	)	x 365	x	(	1.03	$)^3$	16,564
5	(	0.0004	x	950	+	0.823	x	50	)	x 365	x	(	1.03	$)^4$	17,061
6	(	0.0004	x	950	+	0.823	x	50	)	x 365	x	(	1.03	$)^5$	17,573
7	(	0.0004	x	950	+	0.823	x	50	)	x 365	x	(	1.03	$)^6$	18,100
8	(	0.0004	x	950	+	0.823	x	50	)	x 365	x	(	1.03	$)^7$	18,643
9	(	0.0004	x	950	+	0.823	x	50	)	x 365	x	(	1.03	$)^8$	19,202
10	(	0.0004	x	950	+	0.823	x	50	)	x 365	x	(	1.03	$)^9$	19,778

N = 173,775

Traffic Volume: 1,000 vehicles per day, Design CBR: 6%

1 Pavement Structure Design

1.1 Target pavement thickness

The pavement design is based on the TA method used in Japan.

Target pavement thickness is calculated using formula (1.1) based on the Cumulative number of wheels equivalent loads to 5 tons during the design period (N) and the CBR of the subgrade.

$TA=3.84\ N^{0.16} / CBR^{0.3}$ (formula 1.1)

TA : Total pavement thickness converted into an equivalent thickness of hot mix asphalt concrete (cm)

N : Cumulative number of wheels equivalent loads to 5 tons during the design period

CBR : Subgrade CBR (%)

$N = \sum_{i=1}^{n} (N(5\ tons) \times 365 \times ai)$ (formula 1.2)

N : Cumulative number of wheels equivalent loads to 5 tons during the design period

N(5 tons) : Number of equivalent wheel loads of each vehicle/ day

$N(5\ tons)=(Wheel\ loads/5)^4 \times Number\ of\ wheels$

n : Design Period (normally 10 years)

ai: Traffic Growth Ratio

2 Target Total Pavement Thickness (TA)

2.1 Design Condition

Traffic Volume	1000 Vehicles/day	Light Vehicle	950 Vehicles/day	95 %
		Heavy Vehicle	50 Vehicles/day	5 %
Design Period	10 years			
Traffic Growth Ratio	3 %			
Subgrade CBR	6 %			

2.2 Light Vehicle N (5 tons) 2- ton Passenger Car or Light Truck

0.5 ton	0.5 ton
0.5 ton	0.5 ton

Light Vehicle N (5 tons) $= 4 \times (0.5/5)^4$

$= 0.0004$

2.3 Heavy Vehicle N (5 tons) 10- ton Heavy Truck

1.0 ton	4.0 ton
1.0 ton	4.0 ton

Heavy Vehicle N (5 tons) $= 2 \times (1.0/5)^4 + 2 \times (4.0/5)^4$

$= 0.823$

2.4 Cumulative number of wheels equivalent loads to 5 tons during the design period（N）

$$N = \Sigma_{i=1}^{10} \left(950 \times 0.0004 + 50 \times 0.823 \right) \times 365 \times \left(1.03 \right)^{i}$$

$$= 173{,}775$$

2.5 Calculation of TA

$$TA = 3.84 \times \left(173{,}775 \right)^{0.16} / \left(6 \right)^{0.3}$$

$$= 15.5$$

3 Conversion Coefficient

Table 3.1 shows conversion coefficient of pavement structure.

Table 3.1 Conversion Coefficient of pavement Structure.

Pavement Structure		Conversion Coefficient
Asphalt Surface Course		1.00
Base Course	(M-30)	0.35
Bab-base Course	(C-40)	0.25

4 Pavement Structure

4.1 Design Pavement Structure

The pavement three layers: asphalt surface, base course, and sub-base course. Table 4.1 shows minimum thickness of each layer. TA' obtained by multiplying the thickness of each layer by the conversion coefficient shall be set to be equal to or greater than TA.

$TA' = a1T1 + a2T2 + a3T3$ （Formula 4.1）

$TA' \geqq TA$

Table 4.1 Minimum Thickness Each Pavement Structure

Pavement Structure		Minimum Thickness
Asphalt Surface Course		5cm
Base Course	(M-30)	10cm
Bab-base Course	(C-40)	12cm

Note: minimum thickness is 3 times of stone size

4.2 Design of Pavement Thickness

Table 4.2 shows the design pavement thickness (cm) of the three layers of the asphalt surface, base course, and sub-base course.

Table 4.2 Design of Pavement Structure

Pavement Structure		Pavement Thickness
Asphalt Surface Course		5 cm
Base Course	(M-30)	15 cm
Bab-base Course	(C-40)	25 cm

$TA' = 5 \times 1.0 + 15 \times 0.35 + 25 \times 0.25$

$16.5 \geqq TA = 15.5$

Since TA' exceeds TA, the layer thickness in Table 4.2 is used as the design pavement thickness.

N: Cumulative number of wheels equivalent loads to 5 tons during 10 years

1	(	0.0004	x	950	+	0.823	x	50	)	x 365					15,158
2	(	0.0004	x	950	+	0.823	x	50	)	x 365	x	(	1.03	)	15,613
3	(	0.0004	x	950	+	0.823	x	50	)	x 365	x	(	1.03	$)^2$	16,082
4	(	0.0004	x	950	+	0.823	x	50	)	x 365	x	(	1.03	$)^3$	16,564
5	(	0.0004	x	950	+	0.823	x	50	)	x 365	x	(	1.03	$)^4$	17,061
6	(	0.0004	x	950	+	0.823	x	50	)	x 365	x	(	1.03	$)^5$	17,573
7	(	0.0004	x	950	+	0.823	x	50	)	x 365	x	(	1.03	$)^6$	18,100
8	(	0.0004	x	950	+	0.823	x	50	)	x 365	x	(	1.03	$)^7$	18,643
9	(	0.0004	x	950	+	0.823	x	50	)	x 365	x	(	1.03	$)^8$	19,202
10	(	0.0004	x	950	+	0.823	x	50	)	x 365	x	(	1.03	$)^9$	19,778

N = 173,775

Traffic Volume: 1,000 vehicles per day, Design CBR: 8%

1 Pavement Structure Design

1.1 Target pavement thickness

The pavement design is based on the TA method used in Japan.

Target pavement thickness is calculated using formula (1.1) based on the Cumulative number of wheels equivalent loads to 5 tons during the design period (N) and the CBR of the subgrade.

$TA=3.84\ N^{0.16} / CBR^{0.3}$ (formula 1.1)

TA : Total pavement thickness converted into an equivalent thickness of hot mix asphalt concrete (cm)

N : Cumulative number of wheels equivalent loads to 5 tons during the design period

CBR : Subgrade CBR (%)

$N = \sum_{i=1}^{n} (N(5\ tons) \times 365 \times ai)$ (formula 1.2)

N : Cumulative number of wheels equivalent loads to 5 tons during the design period

N(5 tons) : Number of equivalent wheel loads of each vehicle/ day

$N(5\ tons)=(Wheel\ loads/5)^4 \times Number\ of\ wheels$

n : Design Period (normally 10 years)

ai: Traffic Growth Ratio

2 Target Total Pavement Thickness (TA)

2.1 Design Condition

Traffic Volume	1000	Vehicles/day	Light Vehicle	950	Vehicles/day	95 %
			Heavy Vehicle	50	Vehicles/day	5 %
Design Period	10	years				
Traffic Growth Ratio	3	%				
Subgrade CBR	8	%				

2.2 Light Vehicle N (5 tons) 2- ton Passenger Car or Light Truck

0.5 ton	0.5 ton
0.5 ton	0.5 ton

Light Vehicle N (5 tons) = $4 \times (0.5/5)^4$

= 0.0004

2.3 Heavy Vehicle N (5 tons) 10- ton Heavy Truck

1.0 ton	4.0 ton
1.0 ton	4.0 ton

Heavy Vehicle N (5 tons) = $2 \times (1.0/5)^4 + 2 \times (4.0/5)^4$

= 0.823

2.4 Cumulative number of wheels equivalent loads to 5 tons during the design period（N）

$$N = \sum_{i=1}^{10} (950 \times 0.0004 + 50 \times 0.823) \times 365 \times (1.03)^{i}$$

$$= 173,775$$

2.5 Calculation of TA

$$TA = 3.84 \times (173,775)^{0.16} / (8)^{0.3}$$

$$= 14.2$$

3 Conversion Coefficient

Table 3.1 shows conversion coefficient of pavement structure.

Table 3.1 Conversion Coefficient of pavement Structure.

Pavement Structure		Conversion Coefficient
Asphalt Surface Course		1.00
Base Course	(M-30)	0.35
Bab-base Course	(C-40)	0.25

4 Pavement Structure

4.1 Design Pavement Structure

The pavement three layers: asphalt surface, base course, and sub-base course. Table 4.1 shows minimum thickness of each layer. TA' obtained by multiplying the thickness of each layer by the conversion coefficient shall be set to be equal to or greater than TA.

$TA' = a1T1 + a2T2 + a3T3$ （Formula 4.1）

$TA' \geqq TA$

Table 4.1 Minimum Thickness Each Pavement Structure

Pavement Structure		Minimum Thickness
Asphalt Surface Course		5cm
Base Course	(M-30)	10cm
Bab-base Course	(C-40)	12cm

Note: minimum thickness is 3 times of stone size

4.2 Design of Pavement Thickness

Table 4.2 shows the design pavement thickness (cm) of the three layers of the asphalt surface, base course, and sub-base course.

Table 4.2 Design of Pavement Structure

Pavement Structure		Pavement Thickness
Asphalt Surface Course		5 cm
Base Course	(M-30)	15 cm
Bab-base Course	(C-40)	20 cm

$TA' = 5 \times 1.0 + 15 \times 0.35 + 20 \times 0.25$

$15.3 \geqq TA = 14.2$

Since TA' exceeds TA, the layer thickness in Table 4.2 is used as the design pavement thickness.

N: Cumulative number of wheels equivalent loads to 5 tons during 10 years

1	(	0.0004	x	950	+	0.823	x	50	)	x 365				15,158
2	(	0.0004	x	950	+	0.823	x	50	)	x 365	x	(1.03)		15,613
3	(	0.0004	x	950	+	0.823	x	50	)	x 365	x	(1.03)^2		16,082
4	(	0.0004	x	950	+	0.823	x	50	)	x 365	x	(1.03)^3		16,564
5	(	0.0004	x	950	+	0.823	x	50	)	x 365	x	(1.03)^4		17,061
6	(	0.0004	x	950	+	0.823	x	50	)	x 365	x	(1.03)^5		17,573
7	(	0.0004	x	950	+	0.823	x	50	)	x 365	x	(1.03)^6		18,100
8	(	0.0004	x	950	+	0.823	x	50	)	x 365	x	(1.03)^7		18,643
9	(	0.0004	x	950	+	0.823	x	50	)	x 365	x	(1.03)^8		19,202
10	(	0.0004	x	950	+	0.823	x	50	)	x 365	x	(1.03)^9		19,778
													N =	173,775

MINISTRY of WORKS
and TRANSPORT

ADVISOR FOR CAPACITY DEVELOPMENT
IN ROAD CONSTRUCTION AND MAINTENANCE

Road Construction and Maintenance

Drainage

September 2022

Japan International Cooperation Agency (JICA)
Yachiyo Engineering Co., Ltd. (yec)

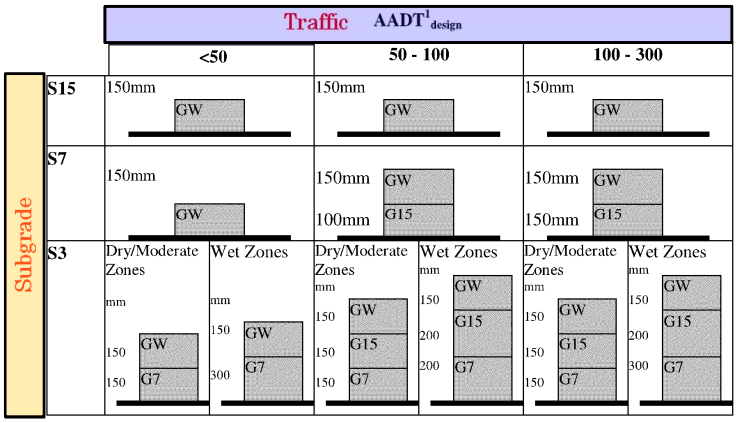
MINISTRY of WORKS
and TRANSPORT

ADVISOR FOR CAPACITY DEVELOPMENT
IN ROAD CONSTRUCTION AND MAINTENANCE

MoWT

Item	Length	Pavement
District Road	38,603 km	DBST
Community Access Road	79,947 km	Gravel

Pavement Structure



Source:
Volume 3: Pavement Design
Part III Gravel Roads

MINISTRY of WORKS
and TRANSPORT
District Road and Community Access Road

Purpose of the Pavement

Keep Road Conditions as Follow

- Safety
- Smooth
- Comfortable

The terrain near the Community Access road is flat and flooded during a rainy season.

The rainwater permeates the road surface and weaken the pavement structure.

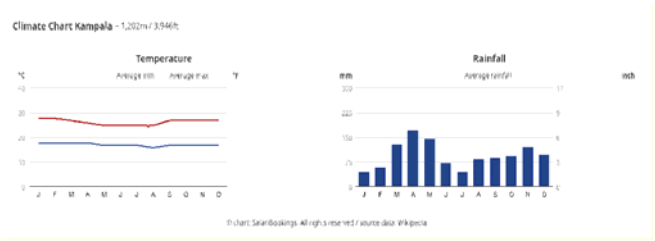
MINISTRY of WORKS
and TRANSPORT
District Road and Community Access Road

Current Condition of the Pavement

Rainwater pond on the road surface.
The road surface is muddy.

Issues of community access road

1. Climate: 2 rainy seasons/ year
2. Terrain: Flat
3. Ground water level: High

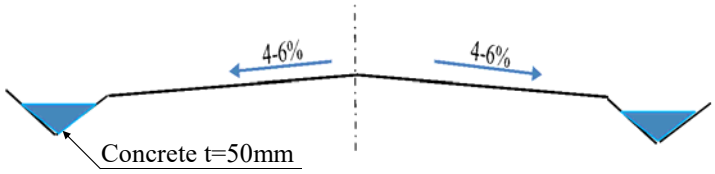


Counter-measures

1. Rainwater:
   Transvers slope and side ditches.
2. Drainage system
   Installation of under-ground drainage
3. Pavement structure
   Review of layer thickness

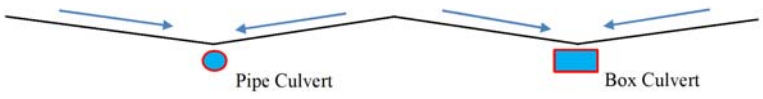
1. Transvers slope and side ditches

Transverse slope shall be 4-6% in order to remove rainwater quickly on the road surface.



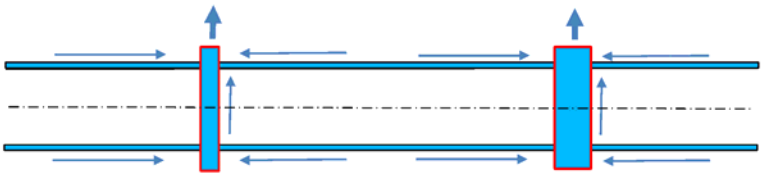
Cross Section

MINISTRY of WORKS
and TRANSPORT
District Road and Community Access Road



Profile

Remarks: vertical slope: minimum 0.3%

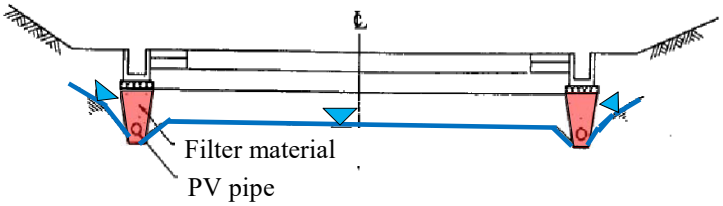


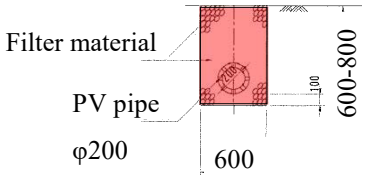
Plan

Pipe Culvert

Install protections on the Inlet and outlet

2. Under-ground drainage





Remarks:

The key point is the drainage of water collected in PV pipe.

Vertical slope shall be minimum 0.3%

3. Pavement layer thickness

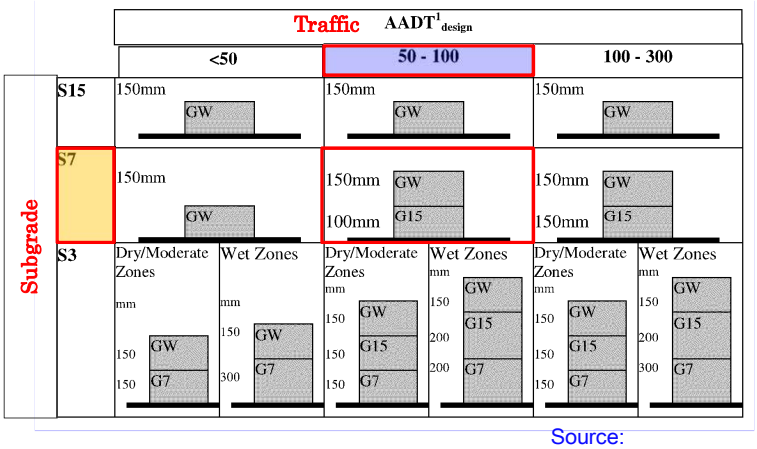
In case of the pavement surface is soaked, the strength of the pavement layer is reduced.

Subgrade CBR⇒20% reduce

Base course granular material elasticity ⇒ 30% reduce

Remarks:
Japanese research institute report

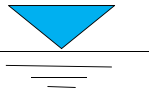
Case Study



Source:
Volume 3: Pavement Design
Part III Gravel Roads

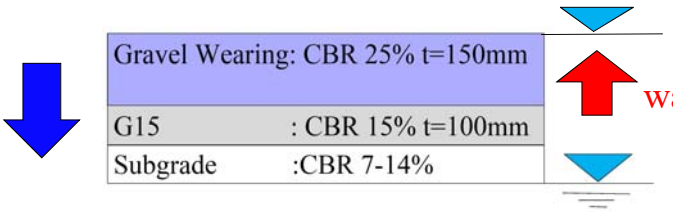
Traffic: AADT 50-100
Subgrade: S7 (CBR 7-14%)

Gravel Wearing: CBR 25% t=150mm	
G15	: CBR 15% t=100mm
Subgrade	:CBR 7-14%



Case Study

This pavement structure does not consider groundwater.



Consider the pavement layer thickness in case of the groundwater level is at the top of the pavement.

Case Study

Design Subgrade CBR 14-7%

Subgrade CBR⇒20% reduce

Design CBR (%)	Soaked :20% reduce
14	11.2
7	5.6

Pavement design formula

- $SN = 3.07N^{0.16}/CBR^{0.3}$

SN : Total Pavement thickness converted into an equivalent thickness of hot mix asphalt. (same as SN)

N : Number of equivalent wheel loads to 49kN (49kNEWLs)

CBR: Design CBR (Subgrade)

Remarks:
Japan Road Association

Pavement thickness

Original

$SN(1)=3.07\ N^{0.16}/(14.0)^{0.3}$

Soaked

$SN(2)=3.07\ N^{0.16}/(11.2)^{0.3}$

→ $SN(2)/SN(1)=1.07$

In case of 20% reduction in subgrade CBR, requires 7% increase in pavement thickness (SN)

Even if the CBR is changed,
the increase rate 7% does not change.

Pavement thickness

$SN=a_1 \times t_1+a_2 \times t_2$

a_i:i^{th} layer coefficient
t_i:i^{th} layer thickness (inches)

Gravel Wearing: CBR 25% t=150mm
G15 : CBR 15% t=100mm

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Pavement Structure

Gravel Wearing : CBR 25

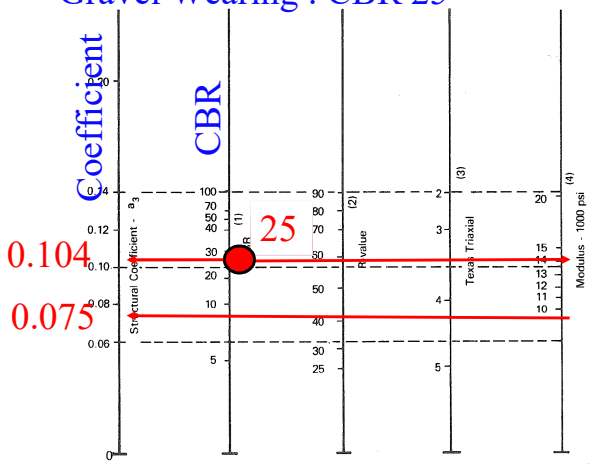


Figure Source:
Design of Pavement Structures (AASHTO)

Granular Base course Coefficient with Strength

MINISTRY of WORKS
and TRANSPORT

Pavement Structure

G 15 : CBR 15

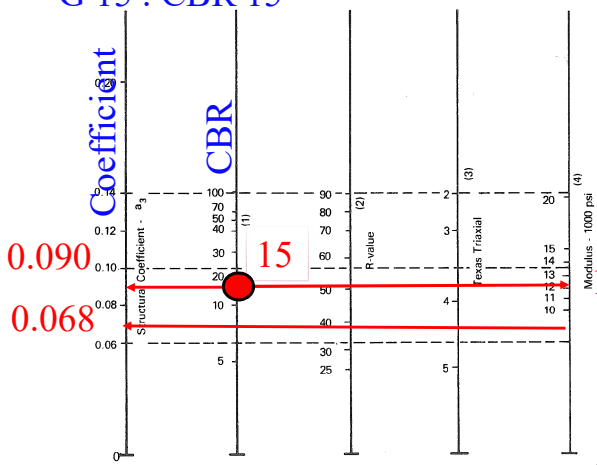


Figure Source:
Design of Pavement Structures (AASHTO)

Granular Base course Coefficient with Strength

Pavement thickness

$SN=a_1 \times t_1+a_2 \times t_2$

$SN=0.104 \times (15/2.54) +0.09 \times (10/2.54)$
$=0.9685$

Gravel Wearing: CBR 25% t=150mm
G15 : CBR 15% t=100mm

* 1 inch = 2.54 cm

Pavement thickness (soaked)

$1.07 \times SN=1.036$

$SN=0.075 \times (17/2.54) +0.068 \times (20/2.54)$
$=1.0374>1.036$ (Soaked required SN)

Gravel Wearing: CBR 25% t=170mm (9%)
G15 : CBR 15% t=200mm (7%)
Subgrade :CBR 7-14% (5.6-11.2)

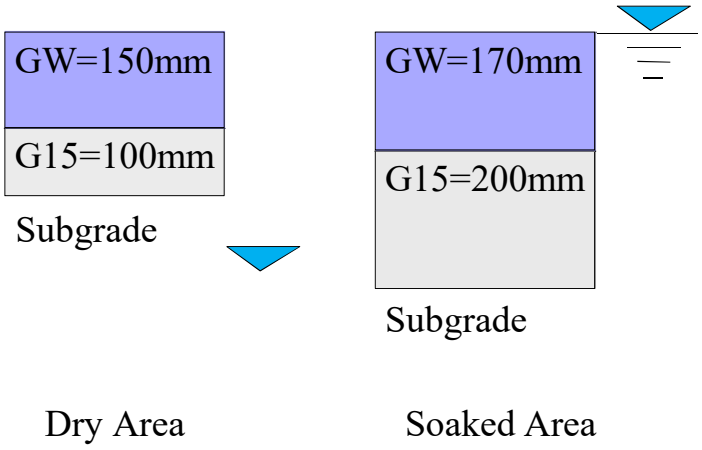
Pavement thickness (soaked)

1.07 x SN=1.036

SN=0.075 x (17/2.54) +0.068 x (20/2.54)
=1.0374>1.036 (Soaked required SN)

Gravel Wearing: CBR 25% t=170mm (9%)	
G15	: CBR 15% t=200mm (7%)
Subgrade	:CBR 7-14% (5.6-11.2)

Pavement thickness (soaked)



Annex 2

Proposed Upgrading of MoWT Mechanical Workshop

1. Central workshop

(1) Building

a) Body Shop, Machine Shop, Welding Shop, Hydraulic Shop, Electrical Equipment Shop, Tire Shop, Machine Shop, Workshop Toilet, etc.

Size：45,000mm x 25,000mm = 1,125m²

Approximate cost：1,125m²x USD4,000/m² = USD4,500,000

b) Workshop office, tool room, office toilet, etc.

Size：7,500mm x 15,000mm = 112.5m²

Approximate cost：112.5m² x USD4,000/m² = USD450,000

c) Warehouse

Size：7,500mm x 10,000mm=75m²

Approximate cost：75m² x USD4,000/m² = USD300,000

Sub-total（a～c） USD5,250,000

(2) Equipment

No.	Shop's name	Equipment name	Q'ty	Price（USD）
1	Body shop	Hydraulic presses, power tools, jacks, hoisting tools, tools, etc.	1 set	478,500
2	Machine shop	Lathes, milling machines, drilling machines, etc.	1 set	321,000
3	Engine shop	Engine stand, engine disassembly and assembly tools, etc.	1 set	85,700
4	Welding shop	Arc welders, gas welding equipment, welding-related tools, etc.	1 set	114,000
5	Hydraulic shop	Cylinder split stand, pump/motor tools, etc.	1 set	107,000
6	Electrical shop	Alternator/starter tester, electric appliance,	1 set	40,000
7	Tire shop	Tire changer, air compressor	1 set	386,000
8	Tool room (tools etc.)	Common use special tools, common use large tools	1 set	178,000
9	Wash equipment	Car wash machine (30,000/unit)	2 units	60,000
10	Spare parts	Parts for machines in each shop	1 set	22,000
11	O/H crane	3 tons capacity (USD115,000/unit)	6 units	690,000
12	O/H crane	5 tons capacity (USD150,000/unit)	2 units	300,000
			Total	USD2,782,200

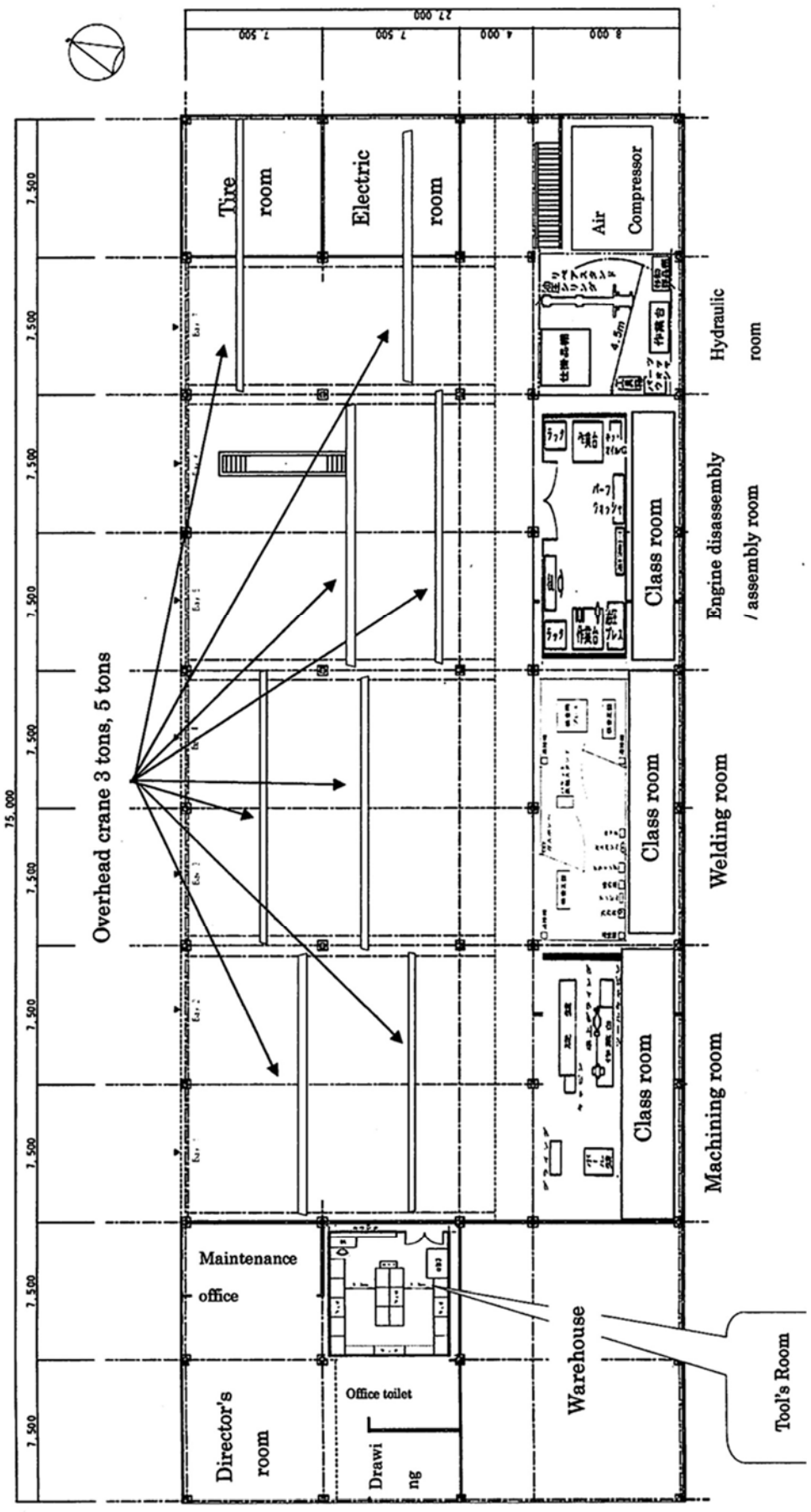
Total of buildings and equipment

(1) Building USD5,250,000

(2) Equipment USD2,782,200

Total amount（1+2）：USD8,032,200

The proposed layout plan (draft) is shown in the next section.



Proposed Layout of MoWT Central Mechanical Workshop

1. Gulu and Mbarara Regional Workshops (Plan A: Renewal by General Building)

(1) Building

a) Body Shop, Machine Shop, Welding Shop, Hydraulic Shop, Machine Room

Size：37,500mm x 25,000mm = 937.5m²

Approximate cost：937.5m²x USD4,000/m² = USD3,750,000

b) Tire shop, tool room, electronics shop, office toilet, etc.

Size：7,500mm x 17,000mm = 127.5m²

Approximate cost：127.5m² x USD4,000/m² = USD510,000

c) Warehouse

Size：7,500mm x 8,000mm = 60m²

Approximate cost：60m² x USD4,000/m² = USD240,000

Sub-total（a～c） USD4,500,000

(2) Equipment

No.	Shop's name	Equipment name	Q'ty	Price（USD）
1	Body shop	Hydraulic presses, power tools, jacks, hoisting tools, tools, etc.	1 set	400,000
2	Machine shop	Lathes, milling machines, drilling machines, etc.	1 set	250,000
3	Engine shop	Engine stand, engine disassembly and assembly tools, etc.	1 set	60,000
4	Welding shop	Arc welders, gas welding equipment, welding-related tools, etc.	1 set	72,000
5	Hydraulic shop	Cylinder split stand, pump/motor tools, etc.	1 set	107,000
6	Electrical shop	Alternator/starter tester, electric appliance,	1 set	40,000
7	Tire shop	tire changer, air compressor	1 set	400,000
8	Tool room (tools, etc.)	Common use special tools, common use large tools	1 set	107,000
9	Wash equipment	Washing machine	2 units	60,000
10	Spare parts	Parts for machines in each shop	1 set	22,000
11	O/H crane	3 tons capacity (USD 115,000/unit)	4 units	460,000
			Total	USD1,978,000

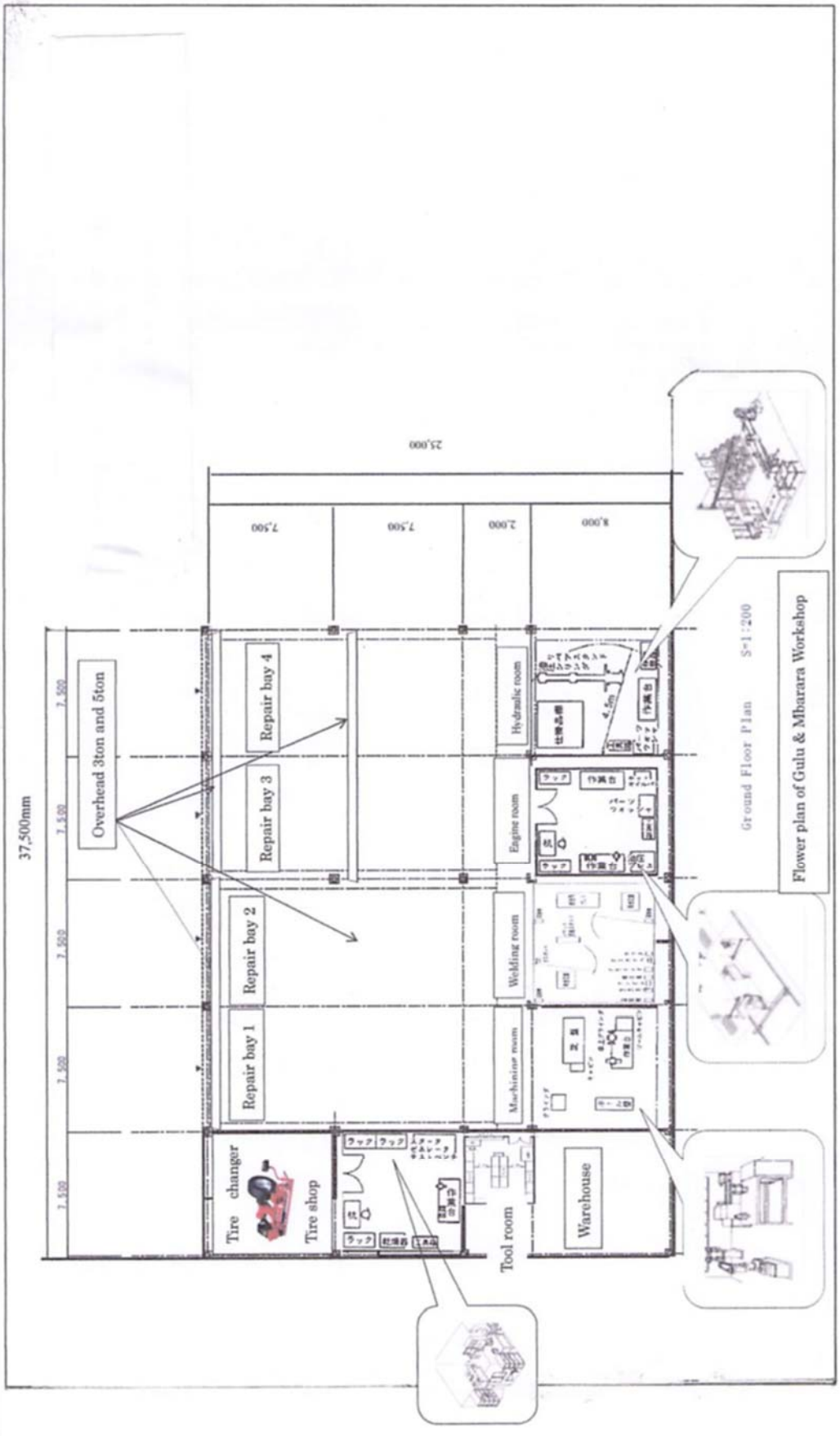
Total of buildings and equipment (per location)

(1) Building USD4,500,000

(2) Equipment USD1,978,000

Total amount（1+2）：USD6,478,000

The proposed layout plan (draft) is shown in the next section.



Proposed Layout of MoWT Regional Mechanical Workshop in Gulu and Mbarara

1. Gulu and Mbarara Regional Workshops (Plan B: Renewal by Simple Container Building)

(1) Building

a) Body shops, tire shops, welding shops, machine shops

Size：15,000mm x 30,000mm = 450m²

Approximate cost：450m²x USD4,000/m² = USD1,800,000

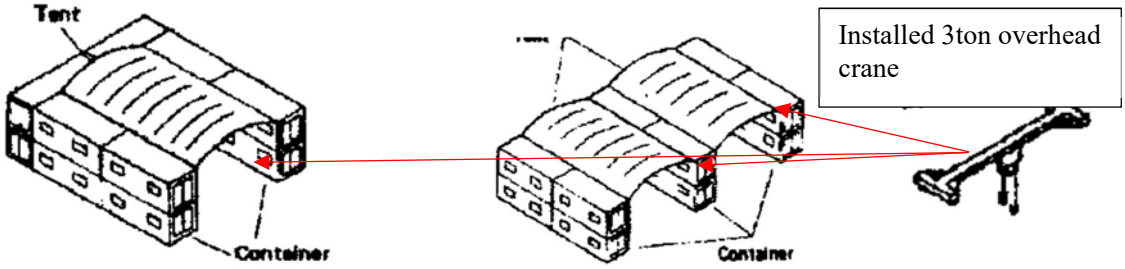
b) Toilet and shower room

Size：5,000mm x 5,000mm = 25m²

Approximate cost：25m² x USD4,000/m² = USD100,000

c) Container 40F & 20F (price including modification cost)

Propose a simple container structure as shown below.



Approximate cost of container structure

No.	Shop's name	Specification	Q'ty	Price（USD）
1	Tool room 40F container	Windows, doorways, tool storage shelves, tool cabinets,	1 set	43,000
2	Office 40F container	Windows, doorways, desks, A/C, document shelves, cabinets, etc.	1 set	22,000
3	Conference room 40F container	windows, doorways, tables, cabinets, A/C projectors	1 set	22,000
4	Warehouse 40F container	Windows, doorways, parts organizing shelves, parts cabinets, desks,	1 set	43,000
5	Electrical shop 40F container	Windows, doorways, cabinets, workbenches, washing tables, etc.	1 set	22,000
6	Men's locker room 40F	Windows, doorways, lockers	1 set	18,000
7	Women's locker room 40F	Windows, doorways, lockers	1 set	18,000
8	Body shop tool room 20F	Windows, doorways, parts organizing shelves, parts cabinets, desks,	1 set	14,500
9	Mechanic office 20F	Windows, doorways, desks, A/C, filing cabinets, cabinets, etc.	1 set	14,500
10	Tire shop tool room 20F	Windows, doorways, parts organizing shelves, parts cabinets, desks,	1 set	14,500

11	Hydraulic shop work room 20F	Windows, doorways, cabinets, workbenches, washing tables, etc.	1 set	22,000
12	Welding shop tool room 20F	Windows, doorways, parts organizing shelves, parts cabinets, desks,	1 set	14,500
13	Fuel pump work room 20F	Windows, doorways, cabinets, workbenches, washing tables, etc.	1 set	22,000
			Total	USD290,000

Sub-total（a～c） USD2,190,000

(2) Equipment

No.	Shop's name	Equipment name	Q'ty	Price（USD）
1	Body shop	Hydraulic presses, power tools, jacks, hoisting tools, tools, etc.	1 set	400,000
2	Machine shop	Lathes, milling machines, drilling machines, etc.	1 set	250,000
3	Engine shop	Engine stand, engine disassembly and assembly tools, etc.	1 set	60,000
4	Welding shop	Arc welders, gas welding equipment, welding-related tools, etc.	1 set	72,000
5	Hydraulic shop	Cylinder split stand, pump/motor tools, etc.	1 set	107,000
6	Electrical shop	Alternator/starter tester, electric appliance,	1 set	40,000
7	Tire shop	Tire changer, air compressor	1 set	400,000
8	Tool room (tools, etc)	Common use special tools, common use large tools	1 set	107,000
9	etc.)	Washing machine	2 units	60,000
10	Wash equipment	Parts for machines in each shop	1 set	22,000
11	Spare parts	3 tons capacity (USD115,000/unit)	4 units	460,000
			Total	USD1,978,000

Total of buildings and equipment (per location)

(1) Building USD2,190,000

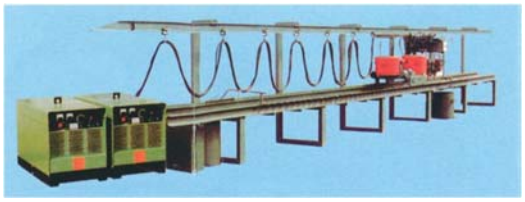
(2) Equipment USD1,978,000

Total amount（1+2）: USD4,168,000

1. Bugembe Regional Workshop

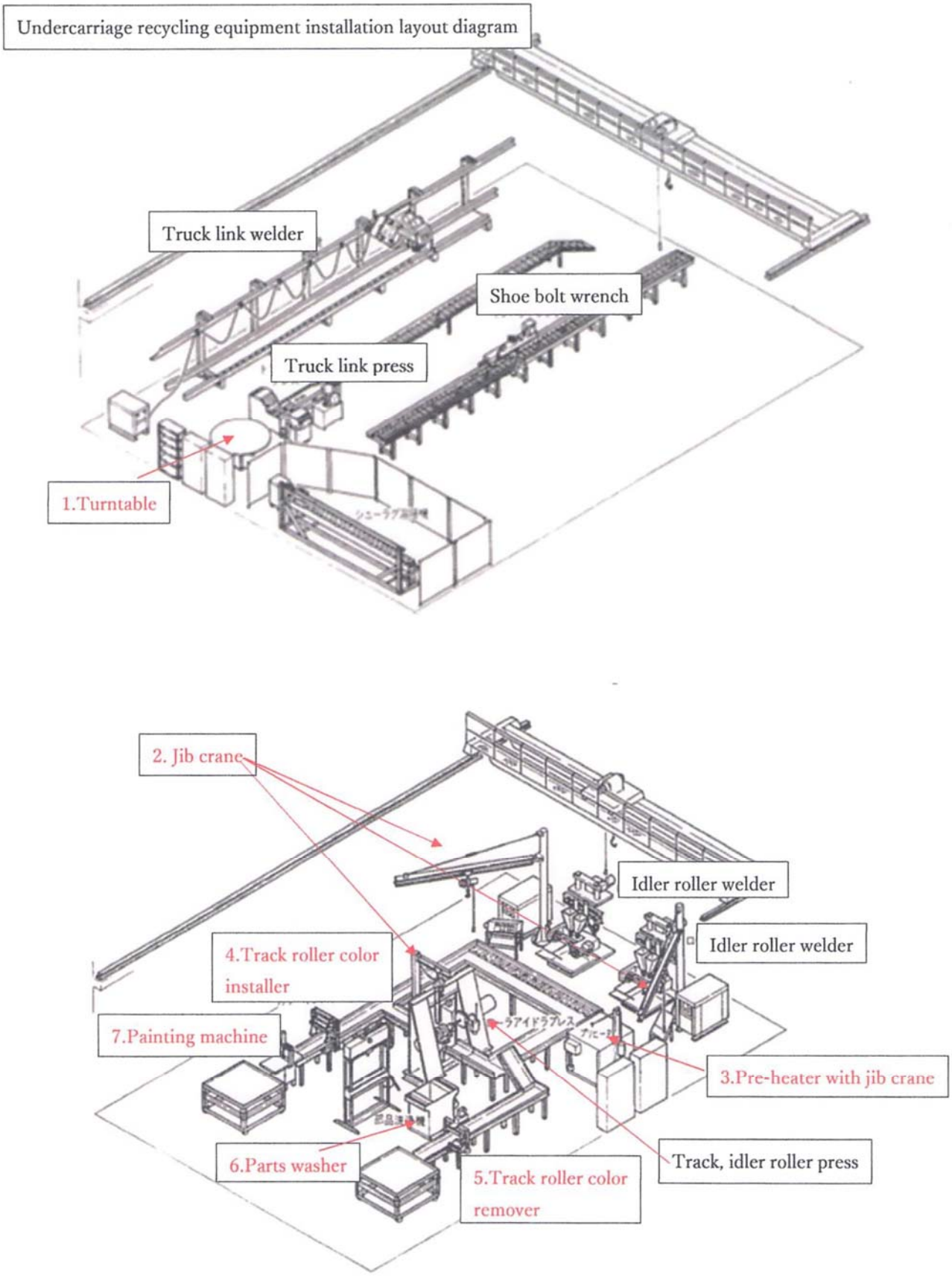
As one of the measures to improve the undercarriage of equipment (excavators, bulldozers) equipped with crawler belts, the introduction of rebuilding undercarriage equipment is conceivable. Reference prices are shown below.

Approximate cost breakdown of undercarriage rebuilding equipment

No	Equipment name and usage	Reference photo	Q't	Price（USD）
1	Track link pin & bush press (supplied tool for D65, D85, PC220) *Machine for detaching and assembling each track link (replacement of pins and bushes, etc.)		1 set	286,000
2	Track link welder *A machine that reconstructs (welds) worn parts of each track link.		1 set	286,000
3	Carrier roller, track roller, idler roller rebuild (welding machine) *Equipment for rebuilding (welding) the worn parts of each roller.	 	1 set	560,000
4	Track roller, idler roller press *Used when disassembling and assembling rollers (overlay after disassembly and reassemble after overlaying).		1 set	220,000
5	Undercarriage Disassembly/Assembly Tools *Various tools for attaching/detaching/assembling the undercarriage of crawler belt running devices such as bulldozers and excavators.		1 set	50,000

6	A set of shoe bolt wrenches and sockets *Impact wrench for removing each shoe bolt.	 	1 set	190,000
7	Flux crusher * A crusher used to crush the hardened flux material and surplus flux material during overlay welding to make recycled products.		1 set	107,200
8	Automatic oil injection and leak detection device *Equipment for inspecting and injecting oil leaks from oil type bottle bushes and roller seals.		1 set	38,000
9	Track link winch * A device that winds up the removed track and makes it easier to store.		1 set	70,000
10	Lathe machine *Equipment that smoothly finishes the surface of the roller, etc. that has been built up.		1 set	150,000
			Total	USD1,957,200

The proposed layout plan (draft) is shown in the next section.



Proposed Layout of Undercarriage Rebuilding Equipment

Annex 3

The Republic of Uganda
Ministry of Works and Transport
Technical Report

Model	Number of Chassis	Number of Engine	Date	Work site (location)
KOMATSU				Mbarara Regional Mechanical Workshop
Mechanic's name	Repair date (inspection date)	Hour meter or Km		Reg. No

Main objective	Photography

Initial failure diagnosis (think about cause of failure)	Yes	No	If not, write a comment

Work contents	Photo of condition during inspection