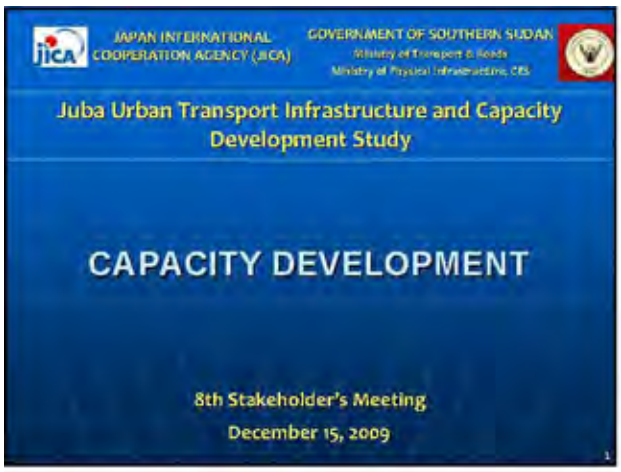
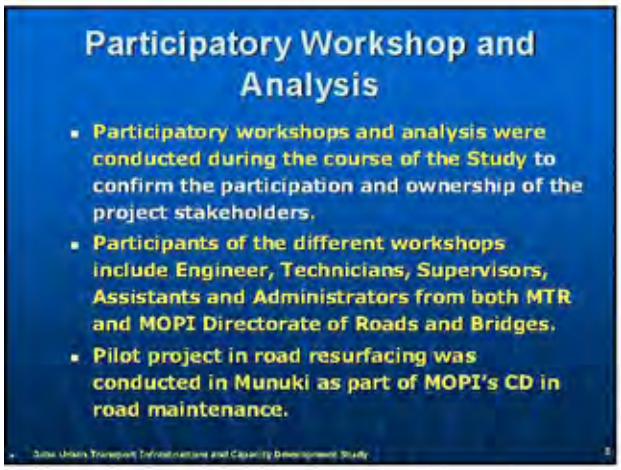
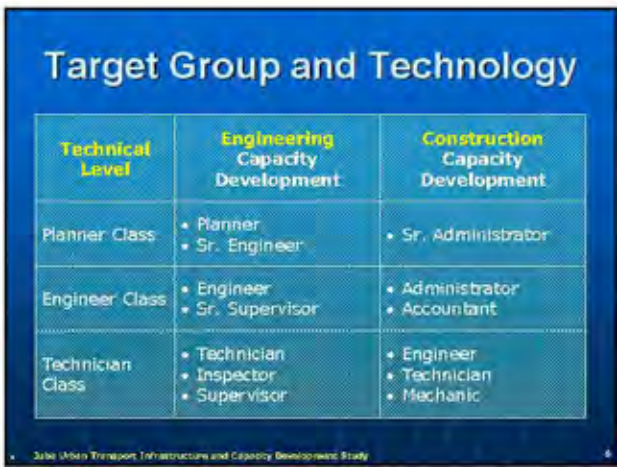
(f) Dr. Jovito Santos

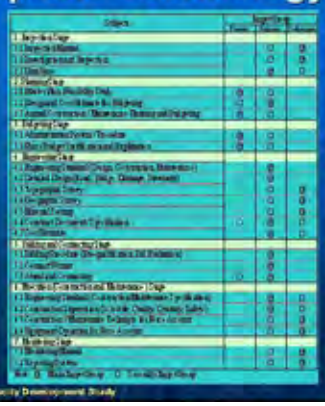






Target Group and Technology

Engineering CD Subjects and Groups



Target Group and Technology

Construction CD Subjects and Groups

Target Group and Technology

Curriculum

- **Effective System for Road Maintenance**
- **Maintenance Techniques for Force-Account**
- **Equipment Operation for Force-Account**
- **Development of Engineering Level**
- **Construction Supervision**

Target Group and Technology

Development Method

- **Technical Cooperation Project Type**
  - Course 1: Seminar / Workshop
  - Course 2: Class Room
  - Course 3: On the job Training
  - Course 4: In service Training
  - Course 5: Training Tour in Foreign Countries
- **Incentive upon Completion**
  - To motivate trainees in capacity development, some incentives should be considered for participants.
    - Provision of suitable employment opportunities and proper professional positions and issuance of diploma

Strengthening of the Private Sector

Roles of the Private Sector

The areas of engineering and construction shall be provided by the private sector which should be responsible for delivering the required services and works through competitive bidding at cost-effective basis.

- **Engineering**
  - The Consultant shall be responsible for rendering engineering services.
- **Maintenance Works**
  - *Private Construction Company* which is suitable for large size maintenance works.
  - *Community-based Road Maintenance Company* which is suitable for small maintenance works.

Strengthening of the Private Sector

Government's Support for the Private Sector

- **To encourage and develop the local construction industry, the government support is absolutely indispensable including the following:**
  - Standard Contractors' Classification System
  - Continuous Supply of Maintenance Projects
  - Establishment of Community-based Road Maintenance Companies
  - Compulsory Engagement of Local Contactor
  - Preference of Local Contractor in International Bidding for Road Project in the country
  - Provision of Access to Credit / Banking / Insurance
  - Practice Training for Business and Engineering

Action Plan

CD Program (1/4)

Program 1: Establishment of Road Maintenance and Management System of the MOPI

Program Objectives	This program aims to establish the practical and effective road maintenance and management system for the MOPI, CIS.
Program Activities	• Recommendation of the road maintenance and management system adaptable for Department of Road Maintenance (DORM) at the MOPI. • Preparation of the annual road maintenance plan and budget for the DORM. • Establishment of Force-account section for road maintenance in the DORM • Development of Contract –out system for road maintenance to private sector. • Capacity Development for the above activities
Counterpart	DORM, MOPI
Target Group	• Planner • Sr. Engineer • Sr. Administration and D.ORM
Input from Foreign Donors	• Sr. Road Management Expert • Sr. Road Maintenance Expert
Duration	Scheduled for two (2) years

Action Plan

CD Program (2/4)

Program 2: Capacity Development of Road Maintenance Technology Under Face- Account Scheme for DORM (F of Project I)

Program Objectives	The program is planned to develop the road maintenance technology through implementing pilot project of the force-account team of the Department of Road Maintenance (DORM), MOPI
Program Activities	• Practice of road inspection and inventory • Selection of pilot sheet suitable for gravel pavement (GP) • Design and cost estimate of gravel pavement of pilot sheet improvement (Pilot Project I) • Study on construction / maintenance method of pavement and drainage • Procurement of construction equipment and materials • Organization of working group mainly composed of community • Execution of road / maintenance work of pilot sheets under force-account scheme • Preparation of road maintenance manual (gravel road) • Evaluation on pilot project implementation • Capacity development for the above activities
Counterpart	DORM, MOPI
Target Group	• Project Manager • Sr. Engineer, Engineer, Technician • Construction supervisor • Equipment operator • Accountant
Inputs from Foreign Donors	• Sr. Highway Engineer • Sr. Road Maintenance Engineer • Procurement of construction equipment and materials
Duration	Scheduled for two (2) years

Action Plan

CD Program (3/4)

Program 3: Capacity Development of Road Maintenance Technology under Contract-out Scheme in Public and Private Sector (Pilot Project II)

Program Objectives	The program aims to develop the road maintenance technology through implementing pilot project in the public sector (the Department of Road Maintenance, MOPI) and private sector (local contractor)
Program Activities	Public Sector • Practice of road improvement and inventory • Selection of pilot sheets suitable for asphalt concrete pavement (AC) • Design and cost estimate of AC pavement of pilot sheets improvement (Pilot Project) • Study on construction / maintenance method of pavement and drainage • Preparation of tender and contract document • Construction supervision of pilot sheets under contract-out scheme • Preparation of road maintenance manual (AC) • Evaluation on pilot project implementation • Capacity development for the above activities Private Sector • Construction site establishment • Procurement of construction equipment and materials
Counterpart	DORM, MOPI
Target Group	Public Sector: • Project Manager • Sr. Engineer, Engineer • Construction supervisor Private Sector: • Construction Manager • Construction Engineer and Technician • Contract Administrator
Inputs from Foreign Donors	• Sr. Highway Engineer • Sr. Road Maintenance Engineer • Project Cost
Duration	Scheduled for two (2) years

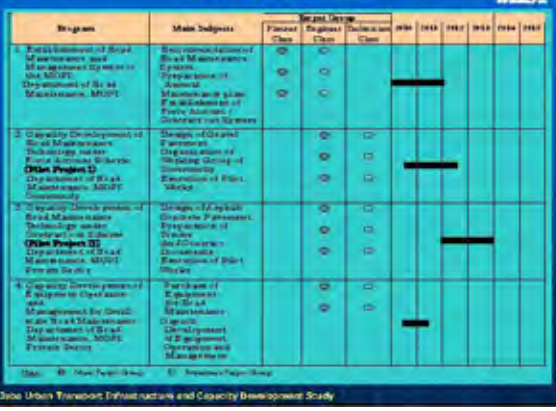
Action Plan

CD Program (4/4)

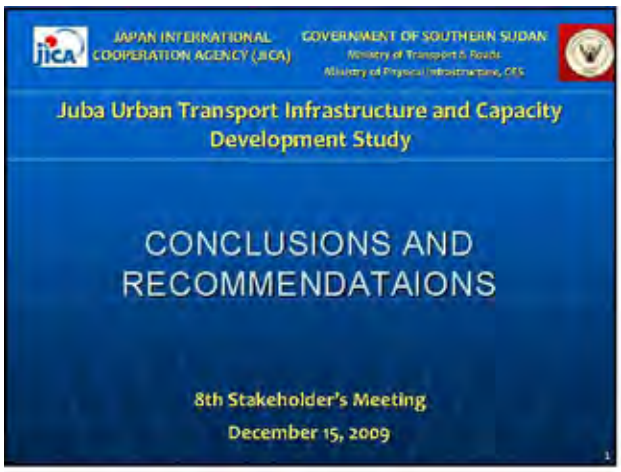
Program 4: Equipment Operation and Management for Small-scale Road Maintenance

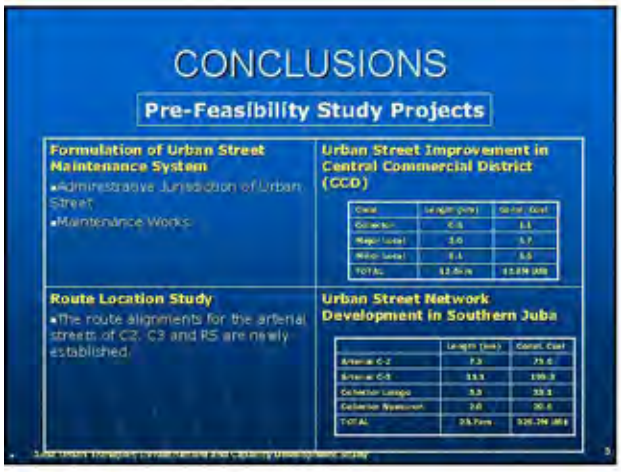
Program Objectives	The MOPI, the DORM is expected to execute the small-scale routine maintenance mainly for small sheets under force-account scheme (still such time, that the maintenance capacity of private contractor will be developed to execute the required work). The program is, therefore, planned to develop equipment operation and management capacity of the MOPI for small-scale road maintenance.
Program Activities	• Purchase of minimum number of equipment for road maintenance required for the MOPI • Preparation of manual for equipment operation and management • Capacity development (Procurement operation and management)
Counterpart	MOPI
Target Group	• Force-account team, DORM, MOPI • Maintenance Engineer • Equipment Operator
Inputs from Foreign Donors	• Sr. Mechanical / Equipment Engineer • Equipment Supply
Duration	Scheduled for one (1) years

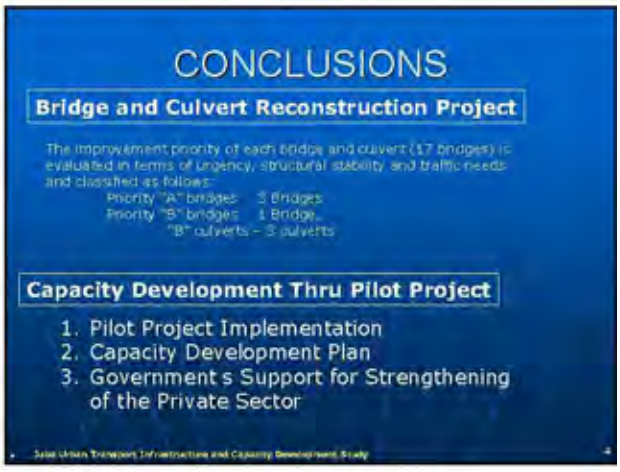
Action Plan



(g) Mr. Tsuneo Bekki







RECOMMENDATIONS

(2) Project Arrangement

- To implement the project as scheduled, such Feasibility Studies and Detailed Engineering Studies should be performed a few years before the commencement of project construction.
- The Feasibility Study on C3 Nile Bridge No.1 (south side) should be conducted as soon as possible.

RECOMMENDATIONS

(3) Constitution of Inter-Ministry Committee fro Transport (IMCT)

- The clear and comprehensive transport development policy, strategy and plan for Juba urban area are indispensable for the development, management and operation of efficient urban transport infrastructures.
- The Inter Ministry Committee for Transport (IMCT) is recommended to be organized in order to discuss and enforce such clear and consistent plan.

RECOMMENDATIONS

(4)Establishment of a Task Force for Road ROW Reservation

- The proposed routes for the arterial streets (4 circumferential streets and 6 radial streets) are identified only at the Pre Feasibility Study level.
- A Task Force is recommended to be established to define the road right of way (ROW) in order to reserve the ROW land and minimize encroachment.

RECOMMENDATIONS

(5) Adoption of Community Based Local Street Maintenance System

- The routine maintenance of local streets if carried out with labor intensive maintenance method by the community based working groups can also be expected to contribute to job creation.
- Community based groups are recommended to be organized with the guidance of the Ministry of Physical Infrastructure (MOPI).

RECOMMENDATIONS

(6) Traffic Safety Education and Enforcement

- When roads are improved, vehicles tend to travel at higher speeds resulting in increase in traffic accident. A traffic safety education program should be established involving education in schools and periodic education of drivers.
- The strengthening of traffic enforcement is also indispensible for maintaining certain urban activities of people and trust by community.

RECOMMENDATIONS

(7) Organization and Human Capacity Development

- An effective organization for the systematic implementation approach is the vital key to the successful realization of the plan.
- Human capacity development programs is the major task that should be strongly instituted to develop the required experience through on the job training and other systemized training programs.


Thank
You

JUTI STUDY

JUBA URBAN TRANSPORT INFRASTRUCTURE AND CAPACITY DEVELOPMENT STUDY

Ministry of Transport and Roads, Yei Road Jebel Kujur, Juba

Government of South Sudan

MINUTES OF DISCUSSION

8th Stakeholder's Meeting
JUTI Draft Final Report Presentation

Purpose	:	**Presentation of the Draft Final Report**
Date and Time	:	**December 15, 2009 (10:00am)**
Venue	:	**Ground Floor Conference Room, Home and Away Restaurant**

Minutes of Discussion:

1. The following highlights the Stakeholders' presentation:
   - MTR (Mr. Otim) presented the different issues relating to the implementation of the Road Network Master consisting of – time frame/time period of implementation, institutional and organizational issues, administrative and technical capacity of MTR and MOPI, urban transport issues and maintenance strategy issues.
   - The Study Team presented the results and summary of the "Juba Urban Transport Infrastructure and Capacity Development Study" including the Overall Implementation Schedule, the Urban Street Maintenance System, Urban Street Improvement in Central Commercial District (CCD), Urban Street Network Development in Southern Juba, Capacity Development and the Study Conclusions and Recommendations.
2. A series of comments and discussions proceeded after the presentation of draft final report with the following highlights:

   2.1. <u>The Proposed Master Plan and the Issue of Road Right-of-Way (ROW)</u>
   - The proposed Juba Urban Road Network Master Plan was appreciated by the stakeholders with the issue of ROW being raised. It was pointed out that the acquisition of ROW should start at present to avoid future costly problems.
   - Encroachment on the road reserve/ROW is a problem in Juba that needs close coordination between MOPI and MTR. MOPI requested MTR to issue the ROW limits of Juba roads which they are willing to protect once defined clearly.
   - With the completion of the Juba road network master plan, the next task would be to mark the required ROW limit for the different proposed roads. The committee that was set-up for the master plan ROW should start preparation for the marking of the road ROW.
   - MTR acknowledge that the master plan will be the reference point for road development in Juba.
   - The provision of space for public utilities within the ROW was clarified with the response that there will be enough space to cover such utilities

2.2. Road Maintenance and Capacity Development for MOPI

- MTR recommends to include the topic on environmental impact assessment for road maintenance projects in the proposed curriculum for capacity development.
- The participants acknowledged the labor-based maintenance system for job creation and improvement of road conditions at the community level.
- It was also pointed out that one of the problems facing the authorities regarding maintenance would be the financial resources necessary to sustain maintenance activities and protect the investments in road infrastructure.

2.3. Traffic Management and Traffic Safety

- MTR pointed out that traffic management and traffic safety are two aspects in road development that has to be looked into by MTR, MOPI and the Police Department.
- An issue on traffic safety is raised, in particular with the Juba Teaching Hospital where conflicts between vehicles and pedestrians cause concerns on traffic efficiency and safety. Recommendations on improving traffic management with traffic signals and pedestrian crossing, relocation of hospital entrance gate, widening the road to provide parking area/bus stops were raised.
- The example of road improvement with road amenities and ancillary facilities including traffic management was cited for the CCD and can be applicable to such area.

2.4. Updating the Master Plan

- Since Juba urban is currently developing at a rapid rate, update of the master plan is necessary according to the changes and development in the region such as socio-economic activities and changes in land use pattern. Master plans are usually updated every ten years but with the rapid changes in Juba urbanization, the update maybe needed much earlier.

2.5. Nile River Bridge

- Plans for the construction of the Nile river bridge was presented and appreciated by the participants. It was acknowledge that Juba will need the second Nile river bridge as soon as possible to support expansion of the socio-economic activities in either side of the Nile river.
- Provision of sufficient navigation clearance was clarified which needs further investigation depending on the future plans of the Department of River Navigation.

3. The Closing Remarks were given by MOPI 1st Dir. Gen Lewis and MTR Dir. Gen. Jacob acknowledging the assistance given by the Government of Japan to Juba thru JICA.

8.4 List of Attendees

JUBA URBAN TRANSPORT INFRASTRUCTURE AND CAPACITY DEVELOPMENT STUDY

Ministry of Transport and Roads, Yei Road, Jebel Kujo, Juba

Government of South Sudan

8TH STAKEHOLDER'S MEETING "JUTI DRAFT FINAL REPORT PRESENTATION"

Conference Room (Ground Floor), Home and Away Restaurant

December 15, 2009

ATTENDANCE SHEET

	NAME	AGENCY/ COMPANY	POSITION	CONTACT NO./E-MAIL	SIGNATURE
1.	Ambrose Chongbi/ Okok	Juba Concrete & Steel Eng. Ltd	Manager	0477101798	
2.	DIM BOWLS	MTR – GOSS		0477112089	
3.	Kiyotaka Tamari	JICA	Project formulation Advisor	011-4636201	
4.	Remo Samuel	Lado & bolivs Co Ltd	Operation manager	0477115369	
5.	Hassan Aggrey	UNC	D/Area Manager	0477124338	
6.	TERRENCE KRAMER	USAID	ENGINEERING ADVISOR	0477-251748	
7.	LEWIS GORE	PHY. INFR.	1ST D/G	0477112564	
8.	[illegible] Meeting	HOUSING	D/G	0477113030	
9.	DR SAMSON PAUL BABA	MOH- GOSS JUBA	D/G	0477195799	
10.	OBIRI DUKE	LBG	PROCUREMENT SPECIALIST	0955017382	
11.	Tsuno Robert	JICA	Team Leader		
12.	Ryuichi UENO	"	Transport Planner		

NAME	AGENCY/ COMPANY	POSITION	CONTACT NO./E-MAIL	SIGNATURE
13. JOVITO SANTOS	JICA STUDY TEAM	MEMBER	santos@cti.co.jp	
14. Chamaraja Aswo Adegbok	LGB	D/G Planning Programmes	09182853 10	
15. Eng. MATU	PWC	MONITORING ENGINEER	+254721283337	
16. Isaac Kuon	"	"	0477248779	
17. SHUSHIDO	JICA	Representative	091-458 9833	
18. Jasob Mamial	MTR	D/G Roads & B.	0477104451	
19. HILARY DADA	MUNUKI Payam	Director	0915376633	
20. Milton Sozini Paul	Juba Municipality	Director Services	012660316 6 or 0477103614	
21. Patricia Labiel	MIA	Environment Ghost	0955008810	
22.				
23. NORIKO TAKAHASHI	JICA	Local consultant	09087 15453	
24. MARY LOBALU	PMT	ADMIN. ASST	0955052419	
25.				
26.				
27.				

APPENDIX 9 NINTH STAKEHOLDER'S MEETING (2nd PILOT PROJECT PRESENTATION)

9.1 Agenda

9TH STAKEHOLDER'S MEETING

2nd Pilot Project Presentation/Workshop

Shalom Hotel & Restaurant

Off Airport Road, Hi Matar, Juba

June 3, 2010

PROGRAM

	Opening Remarks	Peter Laku Loro Ladu Director General Ministry of Physical Infrastructure, CES	10:00 –10:05
	JICA Remarks	Mr. Kenichi Shishido Representative of JICA Sudan	10:05 –10:10
	Munuki Payam Remarks	Mr. Emmanuel Constantino Severino Munuki Executive Director	10:10 –10:15
1.	**Background and Objectives of 2nd Pilot Project**	Dr. Jovito Santos JICA JUTI Study	10:15 –10:25
2.	**Planning and Project Implementation**	Mr. Toyohiro Takagi JICA JUTI Study	10:25 –10:40
3.	**Implementation of Gravel Maintenance by CCG**	Mr. Bullen Pitya Abraham and Mr. Charles Hakim Mila MOPI Directorate of Roads and Bridges	10:40 - 11:00
	COFEE BREAK		11:00 –11:10
4.	**2nd Pilot Project Evaluation**	Dr. Jovito Santos JICA JUTI Study	11:10 –11:25
5.	**MTR Comments and Recommendations on Road Maintenance by MOPI**	Mr. Philip Waiwai and Mr. John Kenyi Sasa Ministry of Transport and Roads, GOSS	11:25 –11:35
6.	**Discussion – Next Steps**	Mr. John Kenyi Sasa Ministry of Transport and Roads, GOSS	11:35 –11:55
	Closing Remarks	Mr. Lewis Gore George 1st Director General Ministry of Physical Infrastructure, CES	11:55 –12:00
	LUNCH		**12:00 -**

9.2 Presentation Material

(a) Dr. Jovito Santos

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

GOVERNMENT OF SOUTHERN SUDAN
Ministry of Transport & Roads
Ministry of Physical Infrastructure, GSS

Juba Urban Transport Infrastructure and Capacity Development Study

2nd Pilot Project Presentation

9th Stakeholder's Meeting
June 03, 2010

Presentation Outline

1. Background and Objectives of 2nd Pilot Project
2. Planning and Implementation
3. Implementation of Gravel Road Maintenance by CCG/MOPI
4. Pilot Project Evaluation
5. MTR Comments and Recommendations on Road Maintenance by MOPI
6. Discussion–Next Steps

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

GOVERNMENT OF SOUTHERN SUDAN
Ministry of Transport & Roads
Ministry of Physical Infrastructure, GSS

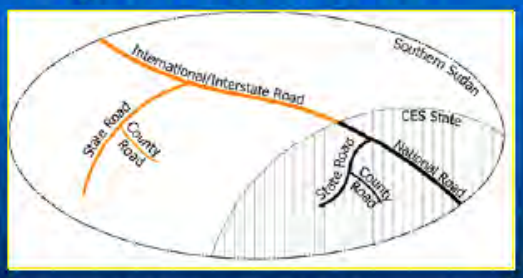
Juba Urban Transport Infrastructure and Capacity Development Study

1. Background and Objectives of 2nd Pilot Project

Session Outline

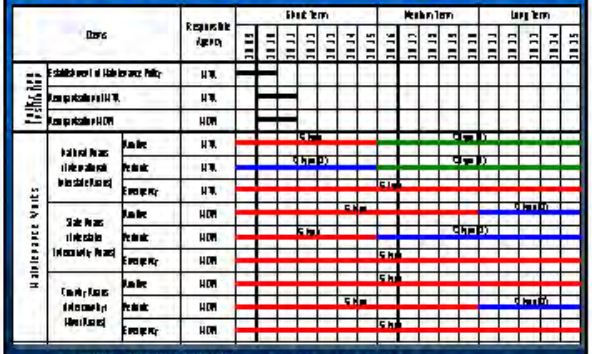
- Background – JUTI Master Plan
- Project Objectives
- Project Approach
- Project Schedule and Organization
- Site Selection
- Site Inspection and Condition
- Project Scope and Outline

Background – JUTI Master Plan

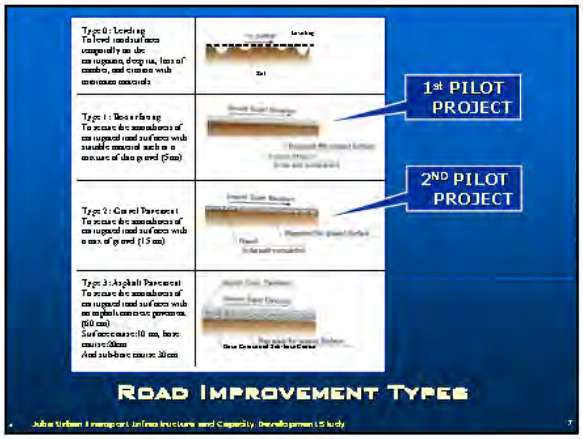


ADMINISTRATIVE ROAD CLASSIFICATION

ROAD MAINTENANCE SYSTEM SCENARIO



■G TYPE– FORCE ACCOUNT ■C TYPE –CONTRACT-OUT

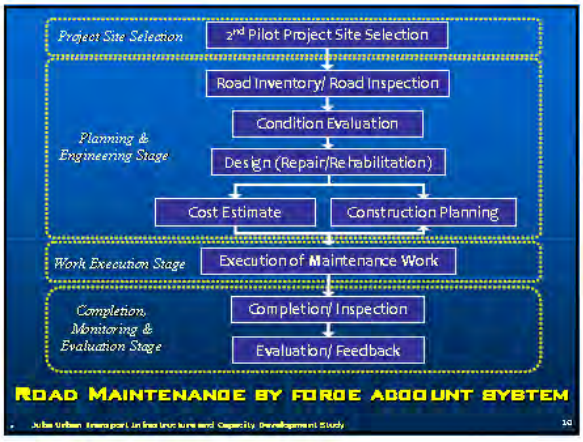


2nd Pilot Project Objectives

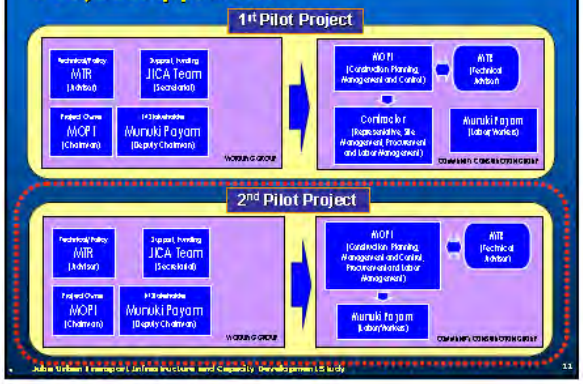
- Assess and assist in improving capabilities of the MOPI in executing periodic maintenance works for gravel roads
- Undertake maintenance/rehabilitation of 500m long gravel road as pilot project type
- Organize community for labor-based gravel road maintenance

ROAD MAINTENANCE STAGES & ACTIVITIES

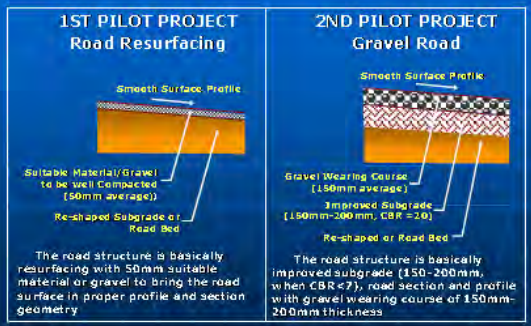
Maintenance Stage	Activities
Inspection Stage	Road Inventory Road Condition Inspection and Evaluation Site Selection for Road Maintenance Project
Planning and Engineering Stage	Coordination with Stakeholders Initial Survey and Basic/Preliminary Design Detailed Design Cost Estimate Scheduling Construction Plan
Budgeting Stage	Requesting Budget for Maintenance Work
Construction Execution Stage	Schedule and Output Management Materials Procurement Management Quality Management Equipment Management Labor Management Financial/ Budget Management and Control Site and Safety Management Facilitating Meeting and Reporting
Monitoring Stage	Final Inspection at Project Completion Monitoring Project Impact Monitoring Performance of Maintenance Works

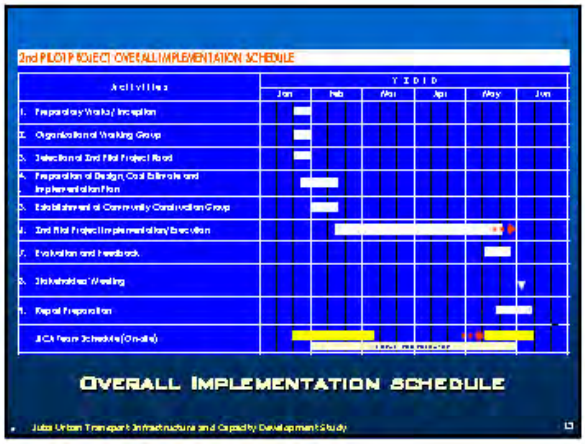


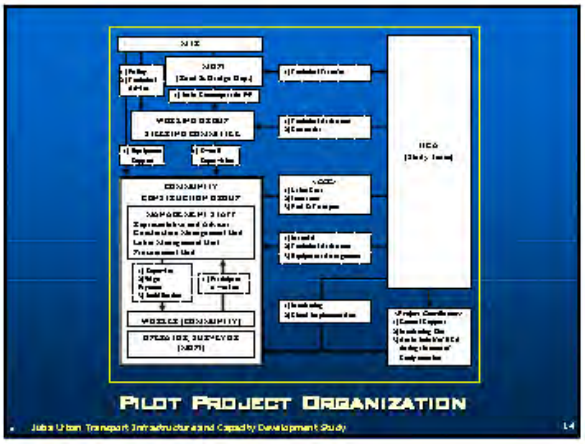
Project Approach

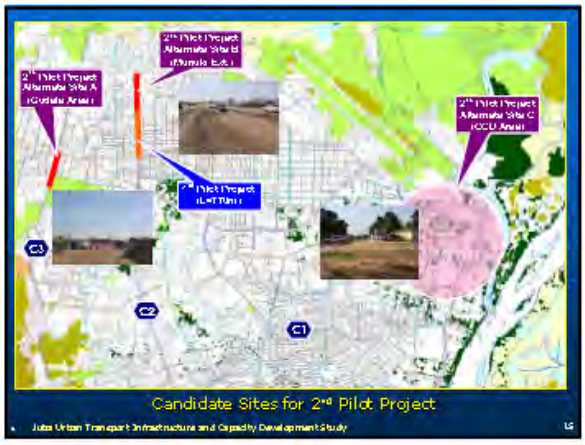


Project Approach

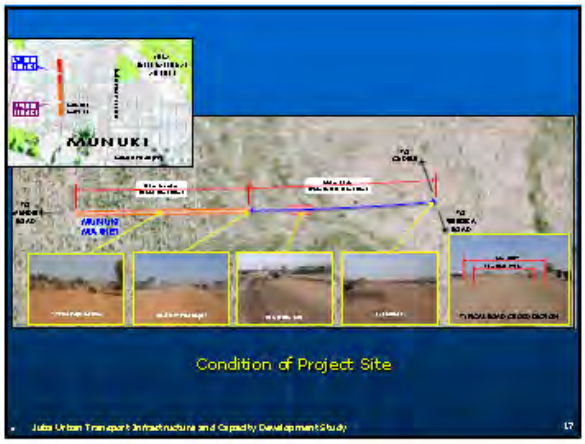


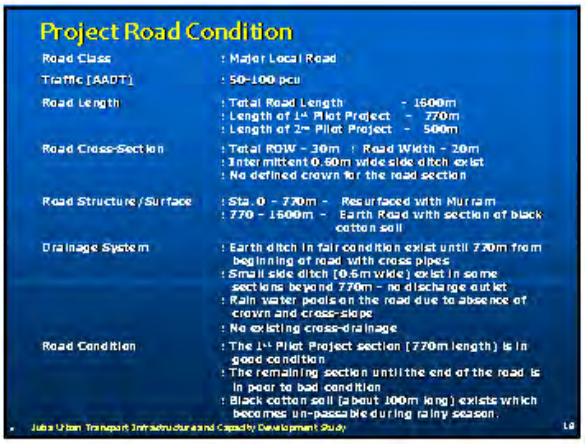

2nd PILOT PROJECT OVERALL IMPLEMENTATION SCHEDULE
Activities
Y 2 0 1 0
Jan
Feb
Mar
Apr
May
Jun
1. Preparatory Works / Inception
2. Organization of Working Group
3. Selection of 2nd Pilot Project Road
4. Preparation of Design, Cost Estimate and Implementation Plan
5. Establishment of Community Construction Group
6. 2nd Pilot Project Implementation/Execution
7. Evaluation and Feedback
8. Stakeholders' Meeting
9. Report Preparation
JICA Team Schedule (On-site)
OVERALL IMPLEMENTATION SCHEDULE
Juba Urban Transport Infrastructure and Capacity Development Study
L3


PILOT PROJECT ORGANIZATION
Juba Urban Transport Infrastructure and Capacity Development Study
L4

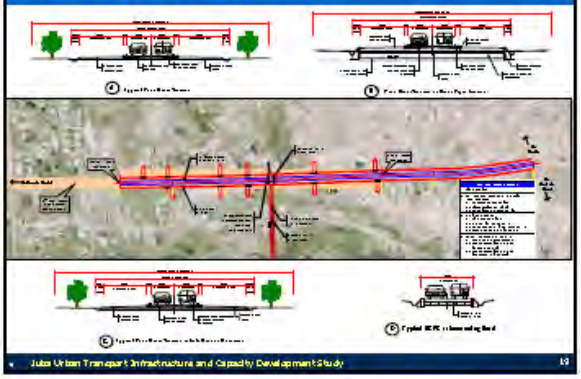

2nd Pilot Project Alternate Site B (Munuki Area)
2nd Pilot Project Alternate Site A (Gudele Area)
2nd Pilot Project Alternate Site C (KCCU Area)
2nd Pilot Project (JETTAM)
C3
C2
C1
Candidate Sites for 2nd Pilot Project
Juba Urban Transport Infrastructure and Capacity Development Study
L5


Site Selection Criteria
• Minimal disturbance on daily activity on site
• Maximum positive impact to community
• Simple and easy to implement
• No duplication with other road projects
• Contributes to improvement of road condition in the area
• Ease of mobilizing and organizing the community
Juba Urban Transport Infrastructure and Capacity Development Study
L6


MUNUKI
Condition of Project Site
Juba Urban Transport Infrastructure and Capacity Development Study
L7


Project Road Condition
Road Class : Major Local Road
Traffic (AADT) : 50-100 pcu
Road Length : Total Road Length - 1600m
: Length of 1st Pilot Project - 770m
: Length of 2nd Pilot Project - 500m
Road Cross-Section : Total ROW - 30m : Road Width - 20m
: Intermittent 0.60m wide side ditch exist
: No defined crown for the road section
Road Structure/Surface : Sta. 0 - 770m - Resurfaced with Murram
: 770 - 1600m - Earth Road with section of black cotton soil
Drainage System : Earth ditch in fair condition exist until 770m from beginning of road with cross pipes
: Small side ditch (0.6m wide) exist in some sections beyond 770m - no discharge outlet
: Rain water ponds on the road due to absence of crown and cross-slope
: No existing cross-drainage
Road Condition : The 1st Pilot Project section (770m length) is in good condition
: The remaining section until the end of the road is in poor to bad condition
: Black cotton soil (about 100m long) exists which becomes un-passable during rainy season.
Juba Urban Transport Infrastructure and Capacity Development Study
L8

General Plan and Sections



Project Outline

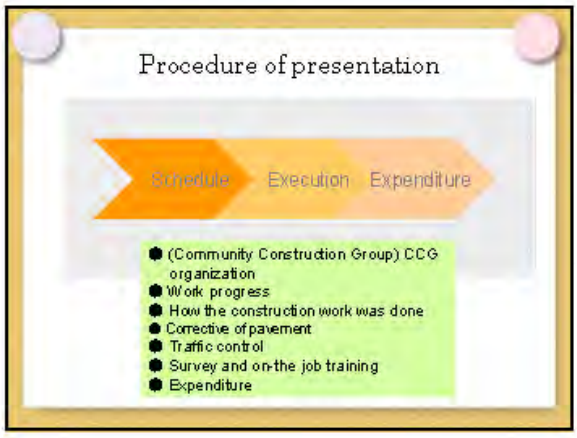
Road Classification	:	Major Local Road
Traffic	:	50-100 pcu/day (Design)
Road Project Length	:	500m
Road Section	:	Travelledway – 2 lanes @ 3.5m/lane = 7.0m Shoulder/Sidewalk – 2 @ 5.5m = 11.0m Ditch – 2 @ 1.0m/ea side = 2.0m Total Road Width = 20.0m
Cross Fall	:	4%
Cross Drainage	:	Ø600mm RC Pipe Culverts Earth canal for discharge of storm water to existing stream channel
Subgrade Improvement	:	Replacement of black cotton soil, L = 100m (0.3-0.6m deep)
Access Road	:	Provision of Ø600mm RC Pipe Culverts,
Road Side Drain	:	1.0m wide earth ditch, L = 800m/ea side
Gravel Wearing Course	:	150mm thick at W = 7.0m for 500m for Travelledway 50mm thick for rest of road section (11.0m wide)

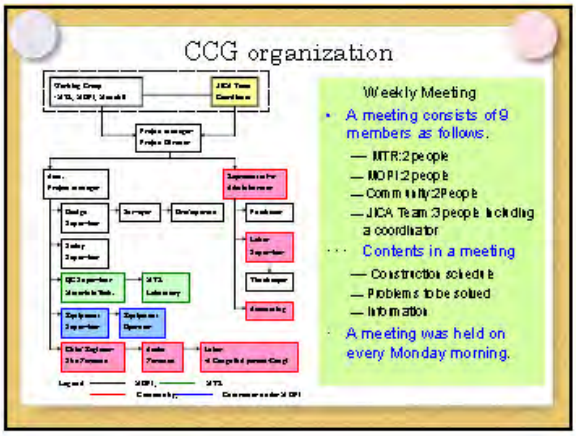
Note:

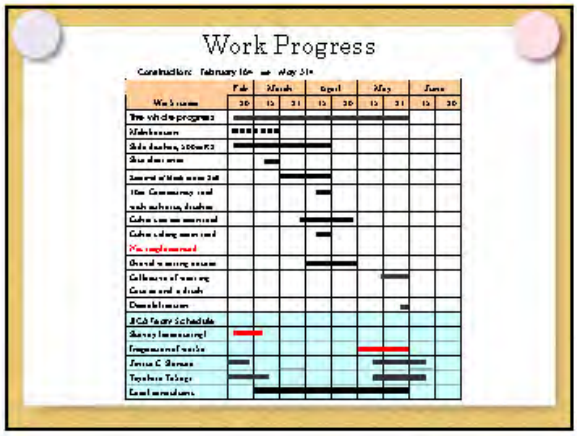
- The 2nd Pilot Project will focus in assessing and improving the MOPI capacity in periodic maintenance of gravel road and not the road project itself.
- Therefore, the project termination is decided when either:
  - the project duration is reached, or
  - the project budget is exhausted

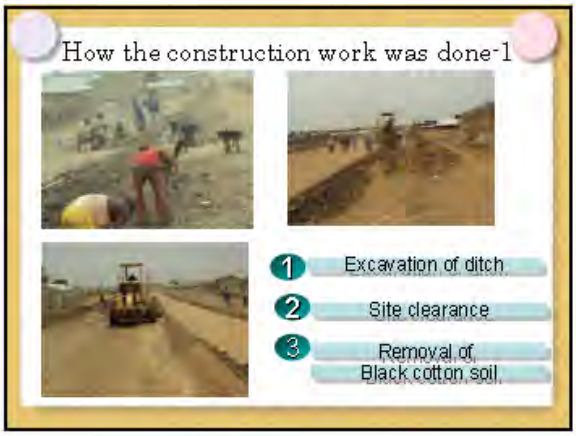
Next Planning and Project Implementation

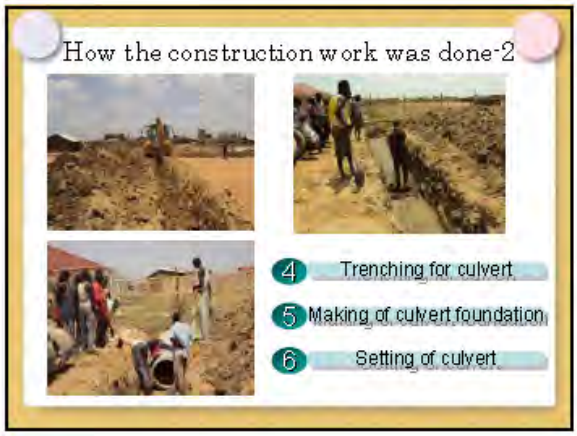
(b) Mr. Toyohiro Takagi











How the construction work was done-3

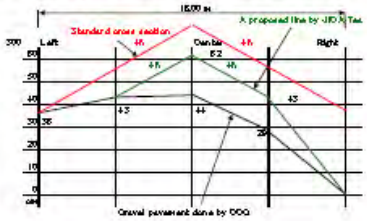
7. Making of culvert wing
8. Construction of 10m road
9. Unloading of gravel

How the construction work was done-4

10. Spreading of gravel
11. Compaction of gravel
12. Condition before inspection

Corrective of pavement-1

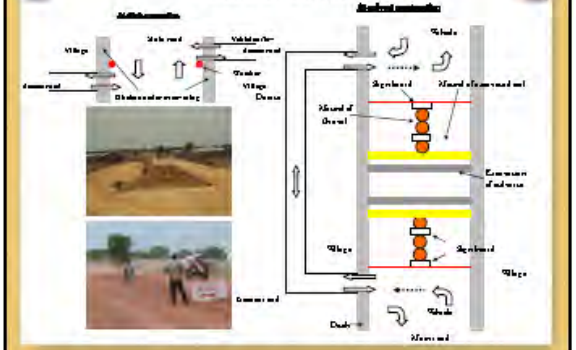
- By a survey of gravel pavement and culverts which already been constructed, JICA Team found a defect, a deviation from standard cross section of pavement. Then corrective work started.



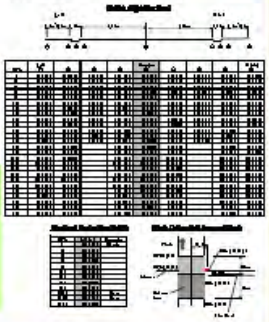
Corrective of pavement-2

- Compute of gravel volume
- Survey ⇨ Spreading ⇨ Confirmation survey ⇨ Compaction

Traffic control



Survey and on-the-job training



Feb.24 to March 1
- JICA Team instructed 2 staffs in how to survey.
- Main subjects;
  - — Leveling
  - — Making alignment of road

Expenses as of May 29th

Category	Items	Amount (SDG)	Remarks
CCD	[illegible]	[illegible]	
	[illegible]	[illegible]	
	[illegible]	[illegible]	
	Sub	[illegible]	
Materials	Gravel	[illegible]	
	Bush Bill	[illegible]	
	Cement	[illegible]	
	Stones	[illegible]	
	Sand	[illegible]	
	[illegible]	[illegible]	
	Culverts	[illegible]	
	Water	[illegible]	
	Small tools/ Wood work	[illegible]	
	Others	[illegible]	
	Sub	[illegible]	
Fuel	[illegible]	[illegible]	
Equipment Rental	[illegible]	[illegible]	
	Sub	[illegible]	
Office	Stationery/ goods	[illegible]	
CDD Tax		[illegible]	
Total		[illegible]	

283,522 SDG

Thank you for your attention

- Next ⇨ Implementation of Gravel Maintenance

Juba Urban Transport Infrastructure and Capacity Development Study

3. IMPLEMENTATION OF GRAVEL ROAD MAINTENANCE BY CCG/MOPI

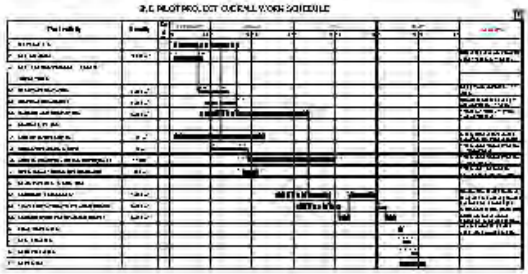
9th Stakeholder's Meeting
June 03, 2010

PRESENTATION OF 2ND PILOT PROJECT AT MUNUKI AREA/JUBA SOUTHERN SUDAN

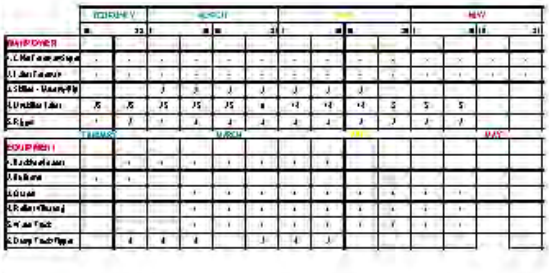
- THE AIM OF THIS PILOT PROJECT FOR CAPACITY DEVEOPMENT OF MTR, MOPI AND MUNUKI PAYAM ON GRAVEL ROAD MAINTENANCE AND CONSTRUCTION
- ALSO ON THE IMPROVEMENT OF MUNUKI ROADS USING THE SKILLED AND UNKILLED WORKERS ON THE PILOT PROJECT TO LEARN MORE FROM ONE ANOTHER

- THIS PROJECT HAD TRAIN STUDENT , AND NONE STUDENT DURING THE HOLIDAYS
- ALSO IT HAS TRAIN PEOPLE FROM THE MINISTRY OF PHYSICAL INFRASTRUCTURE DIRECTORATE OF ROADS AND BRIDGE S ON DIFFERENT ROAD ACTIVITIES
- EXAMPLES,
  - TRAFFIC MANAGEMENT
  - SOIL ANALYSIS
  - ROAD CONSTRUCTION & MAINTENANCE
  - DRAINAGE CONSTRUCTION, AND CONCRTE MIXING

2.5.3.4 CONSTRUCTION PLANNING



Resources /equipment/manpower, traffic management planning Q C plan

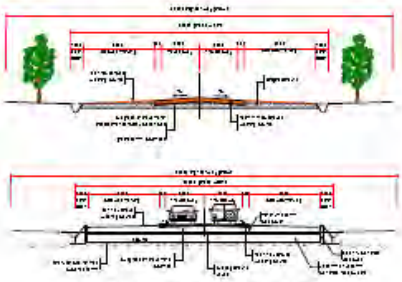


THE ORIGINAL ROAD SURFACE
FIGURE 1

CULVERT CONSTRUCTION
FIGURE 2

AFTER MAINTENACE
FIGURE 3

Figure 4 Typical Road Cross-Section



ROAD EQUIPMENT

- BULL-DOZER
- EXCAVATOR
- GRADER
- ROLLER
- WATER TANKER
- TIPPERS, AND
- ROAD LABARATORY FOR SOIL TESTING

ROLE OF CCG GROUP

- MTR- POLICY MAKING & SUPERVISION
- MOPI- IMPLEMENTATION OF 2ND PILOT PROJECT MAINTENACE AND CONSTRUCTION
- MUNUKI PAYAM – LABOR RECURUMENT AND SUPERVISION
- JICA-ROLE IS FUNDING AND DESIGN MANAGEMENT OF ALL ACTIVITES ON SITE
- CONDUCT MEETING AND MANAGEMENT OF THE PILOT PROJECT

ADVANTAGES OF 2ND PILOT PROJECT

- SECURITY DURING NIGHT
- FREE MOVEMENT OF VEHICLES/PEOPLE
- EMERGENCY CALL OUT IN THE NIGHT
- CHILDREN ABLE TO GO FOR SCHOOLING
- WATER PRICES LOWERING
- LOCAL AREA BUILDING NEW HOUSES
- POLICE WERE ABLE TO PATROL THE AREA
- MARKETING AREA

DISADVANTAGES

- RAIN WATER DIRECTED TO LOWER LAND
- LAND WERE GIVEN TO LOCAL ON VERY LOW AREA
- TRAFFIC MANAGEMENT, NEEDS FOR SPEEDT LIMIT
- DUMPING OF WASTE MATERIALS ON ROAD

REQUESTED TO JICA

- NEED FOR ROAD EQUIPMENTS, EXAMPLES
  - EDM / LEVELLING MACHINES
  - GPS MACHINES FOR EASY LOCATION
  - VECHLES FOR SUPERVISION AND MONITORING OF ROADS
  - COMPUTERS FOR DATA COLLECTION
  - Lab Materials Testing

COMMENTS

- 2ND PILOT PROJECT HAS MADE US TO LEARN FROM EACH OTHER, MTR, MOPI, MUNUKI & JICA STUDY TEAM
- UNDERSTANDING THE TEAM WORKS
- NEEDED FOR CONTUNUING CAPACITY DEVELOPMENT OF MOPI STAFFS, ENGEERS AND TECHNICIANS ON ROAD MAINTENANCES AND CONSTRUCTION , MANEGEMENT

FINAL REMARKS

THANK YOU FOR GIVING ME YOUR TIME & LISTENING

ENG: Bullen pitya Abraham

(d) Dr. Jovito Santos

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

GOVERNMENT OF SOUTHERN SUDAN
Ministry of Transport & Roads
Ministry of Physical Infrastructure, GoS

Juba Urban Transport Infrastructure and Capacity Development Study

4. 2nd Pilot Project Evaluation

Session Outline

- Evaluation Method
- Project Evaluation
  - ✓ Relevance
  - ✓ Effectiveness and Achievement
  - ✓ Efficiency
  - ✓ Impact
  - ✓ Sustainability

Evaluation Method

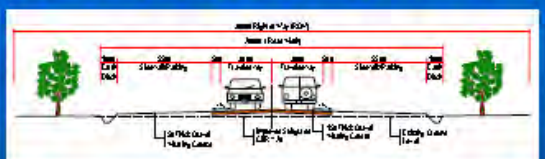
Evaluation Criteria	Description	Evaluation Method	Target Group
1. Relevance	Consistency of purpose and overall goal with MTR, MOPI and the Juba Urban Transport Infrastructure Master Plan and the needs of the local community.	• Questionnaire • Interview • Discussion with W/G and CCG • Review of CCG Reports • Project Site Visit	MOPI MTR Munuki
2. Effectiveness	Assessment of extent of project achievement considering purpose and target output.		MOPI MTR Munuki
3. Efficiency	Analyzing project efficiency with emphasis on the relationships between outputs and inputs in terms of timing, quality and quantity		MOPI MTR
4. Impact	Assessing the project impact - positive and negative.		MOPI MTR Munuki
5. Sustainability	Extent to which the achievements of the projects are sustained or expanded after project completion.		MOPI MTR

1. RELEVANCE

Evaluation Items	Evaluation Results	Recommendations
1. Relevance	• MTR's "Transport Sector Policy" has the objective to "maintain, rehabilitate, improve and construct roads in order to ensure accessibility and minimize the road transport costs". • MTR's "Strategic Plan for the Road Sector" focuses in addressing the training and professional development needs for road development and maintenance thru in-service and on-the-job-training. • JICA Study "Juba Urban Transport Infrastructure" Master Plan recommends improvement and strengthening the capability of the MOPI in road maintenance.	• Although the MTR has a clear policy and strategy in addressing the needs for improving the road infrastructure at the national level, the MOPI, on the contrary, has no clear policy and programs in the aspect of road improvement and maintenance. • MOPI should then establish a definite set of policies, strategies and programs in road development and maintenance and address the issues of strengthening its capacity for road rehabilitation and maintenance.

The Directorate of Roads and Bridges in the MOPI is faced with a big challenge to rehabilitate and maintain the collector and local streets to improve mobility and accessibility in the community and should have the capacity to address the issues of road improvement and maintenance.

2. ACHIEVEMENT AND EFFECTIVENESS



Road Project Length	:	500m Gravel Road + 300m Resurfacing
Gravel Wearing Course	:	150mm thick (7.0m wide) for 500m Trafficway 50mm thick for rest of road section (11.0m wide)
Cross Drainage	:	2x18m -ϕ600mm RC Pipe Culverts for main road 2x10m -ϕ600mm RC Pipe Culverts for cross road
Road Side Drain	:	800m x1.0m wide (2sides) earth ditch for main road 150m (x2sides) earth canal for discharge of storm water to existing stream channel
Subgrade/Ground Improvement	:	Replacement of black cotton soil, L = 100m (D = 0.3)

2. EFFECTIVENESS (SELF EVALUATION)

Road Maintenance Stage	2nd Pilot Project Activities	MOPI	MTR
Inspection Stage	Site Selection for Road Maintenance Project	○	○
	Existing Condition Inspection	○	○
Planning and Engineering Stage	Coordination with Stakeholders	◎	◎
	Site Survey	○	○
	Basic Design	○	◎
	Cost Estimate	○	○
	Work Scheduling	○	○
	Consensus for Planning	○	▽
Construction Execution Stage	Schedule and Output Management	○	▽
	Materials Procurement Management	○	○
	Quality Management	○	▽
	Equipment Management	▽	○
	Labor Management	○	○
	Site and Safety Management	▽	○
	Financial/Budget Management and Control	○	○
	Meeting and Reporting	○	○
Monitoring Stage	Final Inspection at Project Completion	○	○
	Monitoring Project Impact	○	▽

◎ - Very Much Effective ○ - Effective ▽ - Somewhat Effective ■ - Not Effective/Not Sure

2. Achievement and Effectiveness

2. Achievement and Effectiveness

Evaluation Items	Evaluation Results	Recommendations
2. Achievement and Effectiveness	• The project achievement is evaluated based on the performance of the MOPI counterparts in undertaking the pilot project activities. • Project planning was undertaken during the pilot project implementation, but MOPI still need to develop skills in planning for road maintenance project on its own, including: - road inspection and condition evaluation, - design for road maintenance, - cost estimating, value engineering and - construction planning.	• Additional capacity development and technical cooperation programs are necessary to improve further MOPI's technical capability in road rehabilitation and maintenance including: - establishment of road inventory database and computer literacy - preparation of road inspection and road maintenance manuals - planning and design for road rehabilitation and maintenance - technology on road repair and rehabilitation - drainage works - project execution management and quality control

2. Achievement and Effectiveness

Evaluation Items	Evaluation Results	Recommendations
2. Achievement and Effectiveness	• On pilot project works execution, about 500m of road section was improved with gravel and 300m resurfaced. However, MOPI's performance indicated it still need to improve its skills in undertaking such work, including: - interpreting and implementing design and construction plans and specifications, - schedule and output management (daily records of accomplishment), - quality control, - monitoring labor and equipment site productivity, - cost control - facilitating meetings and reporting. • The CDG, as a partnership between MOPI and the Community, is an effective means of undertaking road maintenance project successfully. Involvement of the community is very important in road maintenance works.	• Additional CD on Project Management - Interpreting and implementing plans and design - Labor, equipment, materials, safety management - Quality, cost control - Improving site productivity • Involvement of the Community in road maintenance works including: - basic skills training for labor based maintenance works (masonry, concrete, carpentry, etc.) - repairs of road pavement and road structures (including drainage structures).

2. Efficiency (Input and Output)

Participants

MOPI/CDG	:	1-Construction Engineer, 1-Planner, 1-Administrator, 1-Technician
MTR	:	2-Engineers
Muruki	:	1-Labor Supervisor, 1-Foreman, 1-Timekeeper, 2-Skilled Worker, 1-Security : 5-Gang Leaders, 20-Labor
JICA Team	:	2-Members

Equipment

1 – Excavator/Backloader	-	under MOPI, charges include fuel and maintenance
1 – Roller/Compactor	-	under MOPI, charges include fuel and maintenance
1 – Grader	-	rented out from contractor
1 – Water Truck	-	rented out from contractor
1 – Loader	-	rented out from contractor

3. Efficiency (Input and Output)

Summary of Cost Performance

Work Item	Unit	2nd Pilot Project Cost	Other Project Cost*	Remarks
1. Gravel Wearing Course	$/m²	23.40	(a) 27.50 (b) 23.80	(a) Juba urban roads project (b) Interstate road projects
2. Subgrade Improvement	$/m²	23.70	(a) 38.70 (b) 33.90	(a) Juba urban roads project (b) Interstate road projects
3. Earth Ditch Excavation	$/m²	22.72	(a) 18.00 (b) 12.00	(a) Juba urban roads project (b) Interstate road projects
4. RC Pipe Culvert, 600mmØ	$/m	319.72	340.00	- Juba urban roads project

* Source: MTR

3. Efficiency (Input and Output)

Evaluation Items	Evaluation Results	Recommendations
3. Efficiency (Project Input and Output)	• The pilot project was undertaken with certain limitations in inputs which affected the outcome of the project: • Duration – the constraint of the overall project duration limited the physical output of gravel road maintenance and capacity development. • Budget – the project budget is limited to focus on gravel road structure. • Equipment – problems with availability encountered during project execution has affected project performance, schedule and cost. • Materials – the availability and quality of materials such as gravel wearing course materials and pipe culverts for road drainage caused delays in project schedule.	• Taking into account the local conditions in Juba in terms of availability of resources such as technical staff, materials, equipment and skilled labor, programs for technical cooperation and capacity development should consider sufficient time and duration in implementing similar pilot projects.

3. Efficiency (Input and Output)

Evaluation Items	Evaluation Results	Recommendations
3. Efficiency (Project Input and Output)	Project Counterparts - the number of counterparts from MOPI Directorate of Roads and Bridges limited the benefits of capacity development. • Community Participation -full cooperation of Munuki Payam with the project helped in the smooth project implementation. The project has generated employment within the community and gave the people an experience to work in road maintenance.	• MTR and MOPI should provide sufficient number of counterparts for similar capacity development programs to increase the project's output and efficiency. • More involvement of the Community is recommended in future capacity development/technical cooperation programs.

4. Project Impact

- THE 1ST AND THE 2ND PILOT PROJECTS ENABLED THE COUNTERPARTS OF MOPI AND THE COMMUNITY TO HAVE HANDS-ON EXPERIENCE IN PERIODIC ROAD MAINTENANCE BY RESURFACING AND GRAVEL ROAD TYPES.
- THE COMPLETION OF THE 2ND PILOT PROJECT HAS IMPROVED 1.5KM OF A MAJOR LOCAL ROAD IN MUNUKI WHICH INCREASED MOBILITY AND ACCESSIBILITY IN THE AREA.

4. Project Impact

4. Project Impact

Evaluation Items	Evaluation Results	Recommendations
4. Impact	• The pilot project has contributed to the overall goal of improving the road condition in the area and has led to an increase in mobility and accessibility of the immediate vicinity in the project area. (+) • The MOPI counterparts were able to gain knowledge and experience in implementing proper gravel road maintenance during the course of the pilot project. (+) • The Community benefited during and after completion of the pilot road project thru employment generation, increased business opportunity, increase in mobility and accessibility in the area, improve delivery of services due to road accessibility, improved security in the area, improved public transport and better road drainage. (+)	• The overall positive impacts (within MOPI and the Community) of the pilot road project far outweigh the negative impacts mentioned. In this sense, similar pilot road projects should be undertaken as a technical cooperation project type to improve road conditions in Juba.

4. Project Impact

Evaluation Items	Evaluation Results	Recommendations
4. Impact	• Some negative impacts of the pilot road project in the community include traffic safety concern due to increase in vehicle speeds and local flooding near the streams. (-)	• The concern for traffic safety should be addressed by the proper authority (Police, Traffic Agency, etc.) thru better traffic education and campaign and strict traffic law enforcement. • Drainage system in Juba should be taken at a macro level for the whole urban area considering topography, river systems, rainfall, etc. MTR and MOPI should work on a plan for Juba drainage and flood control system to minimize flood damages on the road and the community.

5. Sustainability

Evaluation Items	Evaluation Results	Recommendations
5. Sustainability	• The sustainability of MOPI capacity strengthening for road maintenance and the improvement in Juba is difficult due to factors including: • Organizational - unclear policy and programs for capacity development - insufficient number of technical staff - insufficient number of equipment for road maintenance - no testing equipment and laboratory to control work quality - no road inventory database as a basis for annual road maintenance plan - no standard manuals and technical guides for road maintenance	• Although the pilot projects (1st and 2nd) contributed to the knowledge and skills of the MOPI counterpart in road resurfacing and gravel road maintenance/rehabilitation, it is obvious that there is a need to broaden and expand the scope of capacity development program for MTR and MOPI to make it more effective and sustainable.

8. SUSTAINABILITY

Evaluation Items	Evaluation Results	Recommendations
5. Sustainability	• Financial – insufficient funds for road maintenance – no fund allocation for human resource development – no funds for road rehabilitation • Individual – need skills improvement in inspection, planning and executing road maintenance works – needs motivation on work responsibilities	• It is thus recommended that a more comprehensive program such as Technical Cooperation Project on Sustainable Road Maintenance be developed for MTR and MOPI to address the organizational, financial and individual issues of capacity development.

(e) Mr. Philip Waiwai

3rd JUNE, 2010
2nd PILOT PROJECT CLOSING MEETING

5.

COMMENTS AND RECOMMENDATIONS

BY PHILIP MARLOW WAIWAI

PROTOCOL,
THANKS GIVING

Director General, State Ministry of Physical Infrastructure and Public Utilities, CES, Juba.

Director General, Directorate of Roads and Bridges, MOPI, CES, Juba.

Senior Administrators, Munuki Payam, CES, Juba.

JAICA Representatives,

Protocol respected. Ladies and Gentlemen.

Pilot Project Objectives.

May I thank JAICA for organizing and funding 2nd PP, intended for ***capacity development*** of MOPI staff and Community of Munuki Payam, to be able to undertake future ***road maintenance management activities.***

Though the objectives of the training may not have been fully achieved, I believe a lot has been learned from the exercise.

COMPARISON BETWEEN MTR AND PP ROAD MAINTENANCE STRATEGIES.

Before the movement that ended by the signing of the CPA between the Government of Sudan (GoS) and the Sudan People's Liberation Movement (SPLM) on 9th January, 2005, former Southern Sudan Regional Government (1972 – 1983) had different system of road maintenance:

Road gangs were recruited and stationed 10 km apart all along the trunk roads in order to execute road maintenance programmes.

With the CPA, the GOSS was formed.

GOSS introduced new system, where by road maintenance is to be contracted to private local contractors (Trained in Kisi, Kenya) and international contractors.

Unlike MTR/GOSS road maintenance policy, JAICA planned to develop the capacity of MOPI staff to be able to manage and carry out the road maintenance activities by themselves.

RECOMMENDATIONS.

By the lessons learned from problems encountered during implementation of the 1st and 2nd Pilot Projects, there is need for the following points to be considered by JICA (And CCG):

1) That thorough review and evaluation of the first two PPs be carried out in order to identify *areas of concern.*

2) That JICA plans another similar training for MOPI staff in all the ten (10) states in order to achieve *Pilot Project objectives.*

3) That emphasis be put on *planning* and *resource* (time, manpower, funds, materials, equipment, etc.) *management skills* that seem to be lacking.

4) That any similar training programme must be closely monitored and evaluated by the facilitators for *better performance and effectiveness.*

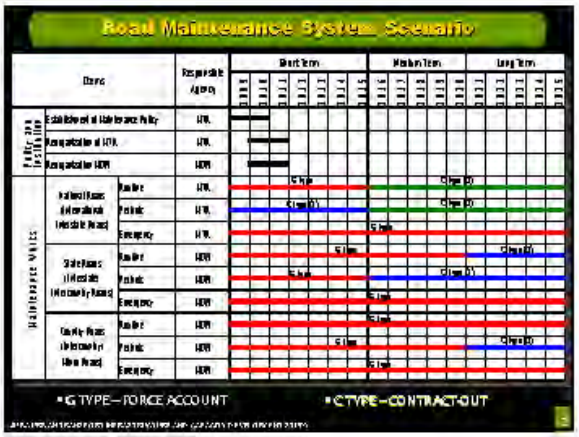
5) *Report* forms/formats be prepared for daily and weekly progress reports.

6) *Report forms* to include: type of activities, required workforce, achieved results, time spent, date and signatures.

7) *Certificate of participation* be issued to the participants at the end of the training period.

Thank you.

(f) Dr. Jovito Santos



Issues	Plans/Required Assistance
◆ Needs Skills and Knowledge Improvements in Executing Maintenance Works : ▪ Schedule Control and Output Management ▪ Management of Site, Labor and Equipment ▪ Quality Control and Testing ▪ Budget and Cost Control ▪ Materials Management ▪ Project Management ▪ Project Evaluation	➢ Preparing Guidelines and Manuals on Project Management and Control ▪ Resources Management/Control ▪ Quality Control ▪ Cost Control ▪ Materials Management ➢ Training in Using and Application of Guidelines and Manuals on Project Management and Control ➢ Training in Project Management ➢ Laboratory and Field Testing Equipment ➢ Pilot Project in Road Rehabilitation and Maintenance ➢ Equipment for Road Maintenance Training

Issues	Plans/Required Assistance
◆ Lack of Technicians ▪ Equipment Operators ▪ Equipment Maintenance Technicians ▪ Laboratory Technicians	➢ Training in Equipment Operation ➢ Training in Equipment Maintenance ➢ Training in Laboratory and Field Testing
◆ Lack of Skilled Workers ▪ Masonry Works for Roads ▪ Carpentry Works ▪ Steel/Rebar Fixer	➢ Cooperation with JICA Vocational Training Center for Training on Masonry, Carpenter and Steel/Rebar Fixer

Issues	Plans/Required Assistance
◆ Lack of Hardware ▪ Computers for Database, Planning and Design ▪ Heavy Equipment for Road Maintenance ▪ Laboratory and Field Test Equipment	➢ Assistance in Procuring ▪ Computers for Database, Planning and Design ▪ Heavy Equipment for Road Maintenance ▪ Laboratory and Field Test Equipment

"JICA and the Study Team expresses its deep appreciation to the Ministry of Transport and Roads and the Ministry of Physical Infrastructure and all the Counterparts for all the support in this Study"

9.3 Minutes of Discussion

MINUTES OF DISCUSSION
9th Stakeholder's Meeting
2nd Pilot Project Presentation

Purpose	:	**Presentation of the results of the 2nd Pilot Project**
Date and Time	:	**June 03, 2010 (10:00am)**
Venue	:	**Conference Room, Shalom Hotel & Restaurant**

Minutes of Discussion:

1. The following highlights the Stakeholders' presentation:
   - The JICA Study Team presented the Background and Objectives of the 2nd Pilot Project, Planning and Project Implementation, 2nd Pilot Project Evaluation and summarized the Next Steps during the discussion. It was pointed out that the 2nd Pilot Project as a capacity development for MOPI focused on gravel road periodic maintenance simulating the force account maintenance system.

     The project evaluation was also presented based on the criteria for relevance, effectiveness, efficiency, impact and sustainability. On effectiveness, it is noted that the MOPI needs more improvement in skills and knowledge for planning and project implementation. The cost effectiveness is compared on work item costs for projects undertaken by the MTR which indicated that the pilot project cost for gravel surface is lower than the Juba urban roads project but higher than the Interstate road projects. Although the cost is slightly higher due to the training component, this can be further reduced once capacity is built and if the MOPI itself manage its own equipment. The overall project impact (especially for the improvement of the community, in terms of accessibility and mobility and daily social life improvement), further outweigh the negative impacts.

   - The MOPI, in behalf of the CCG presented the Implementation of Gravel Maintenance Works under take by the CCG from project planning to implementation. The partnership between MOPI and the Munuki Payam community was highlighted. The MOPI also noted the positive impacts of the project in the Munuki Payam, where accessibility, mobility, security and provision of basic services are improved. Further, it was noted that there is a need for more improvement of the skills and knowledge of the MOPI staffs and the need for support in acquiring equipment and laboratory facilities for road maintenance.
   - The MTR gave their comments and recommendations regarding the 2nd Pilot Project. Although MTR's policy is to contract-out road maintenance for national roads (interstate and international roads), it is acknowledged the pilot project assisted the MOPI in carrying out road maintenance activities by themselves. It is further recommended that similar pilot projects be carried out in the other 10 states.
   - In the discussions, the Study Team presented some issues and recommendations which include: Lack of Road Inventory Database, Need for Skills and Knowledge Improvement in Planning, Design and Execution, Lack of Technicians, Lack of Skilled Workers and Lack of Hardware/Equipment.

2. A series of comments and discussions proceeded after the presentation of draft final report with the following highlights:

1. Munuki Payam.

- The Munuki Payam expressed their appreciation on the JICA Pilot Project which has improved a section of their road network. The Payam's population has increased 3 times since 2006 and community projects by JICA had helped them a lot. However, they need more training in the area to help the people improve their skills and secure better source of income.

2. Plans by Munuki Payam for Pilot Project Participants who have gained some skills in road maintenance.

- On the MOPI's inquiry about the Payam's plans on how to utilize the labor who participated in the pilot project, the Payam responded that they will look into the matter on how to incorporate these participants in their crews. However, the Payam is now contracting-out the cleaning and garbage collection in the area and may have to look into the labor demand.

3. Policy on Road Maintenance

- JICA brought out the issue on road maintenance policy by the Government and ask that it be made clear – force account or contract-out system.
- MTR responded that the MTR's policy is to contract-out the road maintenance but their responsibility is only for the Interstate and International Roads. State roads and County Roads (local roads) are under the jurisdiction of the MOPI (State) but the policy is not yet clear.

4. MOPI's Lack of Equipment

- The MOPI stressed that they lack the equipment necessary for road maintenance and requested assistance for procuring such equipment

The Closing Remarks were given by the Dir. Gen. of Roads and bridge in behalf of the MOPI 1st Dir. Gen Lewis.

ATTENDANCE LIST

JUTI STUDY

JUBA URBAN TRANSPORT INFRASTRUCTURE AND CAPACITY DEVELOPMENT STUDY

Ministry of Transport and Roads, Yei Road, Jebel Kujo, Juba

Government of South Sudan

9TH STAKEHOLDER'S MEETING "2nd Pilot Project Presentation"

SHALOM HOTEL & RESTAURANT

June 3, 2010

ATTENDANCE SHEET

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12. JOVITO SANTOS	JICA STUDY TEAM	MEMBER		

NAME	AGENCY/ COMPANY	POSITION	CONTACT NO./E-MAIL	SIGNATURE
13. TAKAGI TOYOHIRO	JICA STUDY TEAM	MEMBER		高木
14. Yuko MIZOTA	CTII	GM		

APPENDIX 10 DESCRIPTION OF DAILY MAINTENANCE WORKS (UNDER CHAPTER 16)

Cleaning of Road Surface and Drains

Activity:	Cleaning of Road Surface (Labour-based)				CR
Description of Work					
Cleaning shall consist of the removal of brush, other vegetation, rubbish, and all other objectionable material. Material obtained from cleaning shall be disposed of in borrow pits or other suitable places and covered up with soil or gravel.					
Assumed Quantity of Maintenance Works (Daily)					
		Local	Local	Collector	Arterial
		ER/GR	AC	AC	AC
Road Width (Approx.)		W=10 m	W=10m	W=20m	W=40 m
Road Length (km)		1 km	4 km	2 km	1 km
Labour					
Supervisors		1	1	1	1
Skilled		1	1	1	1
Unskilled		20	20	20	20
Equipment					
1	Picup Truck	1	1	1	1
Tool					
2	Shovel	2	2	2	2
3	Hoe	2	2	2	2
4	Broom	20	20	20	20
5	Cutlasses	2	2	2	2
6	Wheel Barrow	2	2	2	2
Materials		–	–	–	–

Activity:	Cleaning/Reparing of Drain (Labour-based)				CD
Description of Work					
The original section of drain should be maintained to remove debris, siltation and grass and reshape the damaged and eroded section in order to provide smooth stable slope and ensure free flow of dischage water. Waste material from ditch cleaning should be deposited in a sutable location.					
Assumed Quantity of Maintenance Works (Daily)					
		ER/GR	AC		
Road Length (km)		1 km	2 km		
Labour					
Supervisors		1	1		
Skilled		1	1		
Unskilled		20	20		
Equipment					
1	Picup Truck	1	1		
Tool					
2	Shovel	2	2		
3	Hoe	2	2		
4	Broom	20	20		
5	Cutlasses	2	2		
6	Wheel Barrow	2	2		
Materials		–	–		

AC: Patching

Activity:	Patching				PA
Description of Work					
With all patching work, it is important to remove the failed area entirely and to cut the road back to sound material. The sides and bottom of the patch should be squared-off to provide a firm coherent surface. Where bituminous patching material is to be used, the excavated and trimmed area should be carefully brushed, moistened slightly with water and painted with bitumen emulsion or rapid-curing cut-back so as to provide a good bond with the in-filling material. The material should be compacted into the hole in 50-70mm layers using hand-rammers or a small vibrating roller. The surface of the completed patch should be slightly higher than the road surface so as to permit final compaction by traffic.					
Procedures of Patching Work					
Step 1 Ripping of existing pavement slab at the failed area Step 2 Removing of base course and sub-base course damaged Step 3 Leveling and compacting of sub-base course and base course Step 4 Tack Coat Spraying, paving of binder course and/or wearing course Step 5 Compacting					
Assumed Quantity of Maintenance Works (Daily)					
Number of Potholes		4	spots/day		
Labour					
	Supervisors	1			
	Skilled	2			
	Unskilled	5			
Equipment					
1	Small Truck	1			
2	Hand Rammer	1			
Tool					
3	Asphalt Sprayer	1			
4	Pic-axe	1			
5	Broom	1			
6	Shovel	1			
7	Drum for water	1			
Materials					
1	Asphalt Mixture	0.013 m3	0.5m x 0.5m x 0.05m		
2	Gravel	0.13 m3	0.5m x 0.5m x 0.5m		

AC: Sealing

Activity:	Sealing				SE
Description of Work					
This is used where reflection cracking has occurred and the aim is to fill the cracks as completely as possible with bituminous binder to keep out water. Bitumen emulsion can use for sealing the cracks. Sealed cracks may be blinded with quarry fines.					
Assumed Quantity of Maintenance Works (Daily)					
Number of Potholes		4	spots/day		
Labour					
	Supervisors	1			
	Skilled	2			
	Unskilled	3			
Equipment					
1	Picup Truck	1			
Tool					
2	Asphalt Sprayer	1			
3	Broom	2			
Materials					
1	Asphalt Emulsion	2 liter	4 spots/day		
2					

GR: Re-Gravelling

Activity:	Regravelling (Equipment-based)			No.	RG-E
Description of Work					
A gravel surface should be spread in a depth of about 5 inch to protect the earth surface. Tippers circulate continuously between the quarry and the site. The gravel is supplied in advance and tipped in heaps on one side of the road at the correct spacing to give the required thickness of material when spread across the road. The gravel is then spread right across the road using the grader, and watered by the tanker until its moisture content is correct for compaction. Once the material has been spread evenly across the road and it is at the correct moisture content, it should be graded to shape. The camber of the gravel surface should be checked to ensure that it is between 4 and 6 per cent. Finally, the camber should be checked with the camber board and, if the required standard has not been reached, the grading should be repeated.					
Assumed Quantity of Maintenance Works (Daily)					
		AC			
Road Length		1.3 km	9m x 0.125 m x 1.0 km x 20%=225 m3 (300 m3/day)/225 m3 =1.3 km/day Reference: 300 m3/day (British Road Note)		
Labour					
	Supervisors	1			
	Skilled	13			
	Unskilled	20			
Equipment					
1	Tipper Truck	9	3 trucks/100m3 (Hauling Distance: 10km)		
2	Grader	1			
3	Roller	1			
4	Wheel Loader	1			
5	Water Truck	1			
Tool					
6	Shovel	1			
Materials					
1	Gravel	300 m3			

GR: Re-Shaping/Re-Grading

Activity:	Regrading (Equipment-based)			No.	RES-E
Description of Work					
Re-grading/re-shaping should be carried out on the basis to restore a smooth riding surface and cross fall by removing spots, moving the loose material and reshaping the surface to repair potholes, corrugations, erosion gullies and wheel ruts. Cross fall on gravel and earth roads should be between 4-6 per cent to minimize the erosion by discharging surface rainfall water. Patching is to be needed on gravels containing large lumps of material. Loose material and standing water should then be brushed from the area to be repaired. Large or deep pot-holes and defects should have their sides cut back and should be deepened to reach sound material. The patch and defects should then be filled in layers not exceeding 10 cm at a time. Each layer should be compacted with roller or with small vibrating compactors. The layers of the patch should be built up in this way and, finally, the patch is filled with gravel to approximately 30mm above the level of the road surface and is spread and raked to the correct shape. The patch is then compacted to give a surface which is slightly above the level of the surrounding road. Loose materials should be stockpiled at the nearest maintenance camp or dumped by the side of the road near where it will be used. Loose rocks, roots and grass shall be removed.					
Assumed Quantity of Maintenance Works (Daily)					
		AC			
Road Length		0.6 km	9m x 0.3 m x 1.0 km x 20%=540 m3 (300 m3/day)/540 m3 =0.6 km/day Reference: 300 m3/day (British Road Note)		
Labour					
	Supervisors	1			
	Skilled	13			
	Unskilled	20			
Equipment					
1	Tipper Truck	9	3 trucks/100m3 (Hauling Distance: 10km)		
2	Grader	1			
3	Roller	1			
4	Wheel Loader	1			
5	Water Truck	1			
Tool					
6	Shovel	1			
Materials					
1	Gravel	300 m3			

ER: Re-Surfacing

Activity:	Re-surfacing (Equipment-based)				RS
Description of Work					
A gravel surface should be spread in a depth of about 50 mm to protect the earth surface. Tippers circulate continuously between the quarry and the site. The gravel is supplied in advance and tipped in heaps on one side of the road at the correct spacing to give the required thickness of material when spread across the road. The gravel is then spread right across the road using the grader, and watered by the tanker until its moisture content is correct for compaction. Once the material has been spread evenly across the road and it is at the correct moisture content, it should be graded to shape. The camber of the gravel surface should be checked to ensure that it is between 4 and 6 per cent. Finally, the camber should be checked with the camber board and, if the required standard has not been reached, the grading should be repeated.					
Assumed Quantity of Maintenance Works (Daily)					
		AC			
Road Length		1.3 km	9m x 0.05 m x 1.0 km x 50%=225 m3 (300 m3/day)/225 m3 =1.3 km/day Reference: 300 m3/day (British Road Note)		
Labour					
	Supervisors	1			
	Skilled	13			
	Unskilled	20			
Equipment					
1	Tipper Truck	9	3 trucks/100m3 (Hauling Distance: 10km)		
2	Grader	1			
3	Roller	1			
4	Wheel Loader	1			
5	Water Truck	1			
Tool					
6	Shovel	1			
Materials					
1	Gravel	300 m3			

ER: Re-Shaping/Re-Grading

Activity:	Re-grading/Re-shaping (Labor-based)			No.	RES-L
Description of Work					
Re-grading/re-shaping should be carried out on the basis to restore a smooth riding surface and cross fall by removing spots, moving the loose material and reshaping the surface to repair potholes, corrugations, erosion gullies and wheel ruts. Cross fall on gravel and earth roads should be between 4-6 per cent to minimize the erosion by discharging surface rainfall water. Patching is to be needed on gravels containing large lumps of material. Loose material and standing water should then be brushed from the area to be repaired. Large or deep pot-holes and defects should have their sides cut back and should be deepened to reach sound material. The patch and defects should then be filled in layers of about 50-70mm at a time. Each layer should be compacted with hand rammers or with small vibrating compactors. The layers of the patch should be built up in this way and, finally, the patch is filled with gravel to approximately 30mm above the level of the road surface and is spread and raked to the correct shape. The patch is then compacted to give a surface which is slightly above the level of the surrounding road. Loose materials should be stockpiled at the nearest maintenance camp or dumped by the side of the road near where it will be used. Loose rocks, roots and grass shall be removed.					
Assumed Quantity of Maintenance Works (Daily)					
Road Length		100 m			
Labour					
	Supervisors	1			
	Skilled	2.7			
	Unskilled	20	Volume by one unskilled labour: 2.7 m3/day (2.5 to 3 m3/day) 9m x 0.3 m x 100 m x 20%=54 m3 54/(2.7 m3)= 20 labours Reference: 3 m3/day (British Road Note) 2.3 person/10m3 (Japanese Standard)		
Equipment					
1	Tipper Truck	1.6	3 trucks/100m3 (Hauling Distance: 10km)		
2	Hand Rammer	1	1 rammer/50m3		
Tool					
3	Pick-axe	1			
4	Shovel	1			
5	Hoe	1			
6	Wheelbarrow	1			
7	Camber Board	1			
8	Sprit Level	1			
Materials					
	Earth/Gravel approved on site	54 m3			

APPENDIX 11 PAVEMENT DESIGN OF STRRETS IN CENTRAL COMMERCIAL DISTRICT (CCD) (UNDER CHAPTER 17)

(1) Pavement Type and Design Sections

Road Network in CCD

As shown in Figure 1, the streets in the CCD are functionally classified into the following 4 categories:

- Arterial Streets (component roads of C-1, C-2 and R-5)
- Collector Streets
- Major Local Streets
- Minor Local Streets

Figure 1 Road Network in CCD

Pavement Type

Considering that the CCD is the busy area with relatively high traffic demand, the following type of pavement is proposed:

- Arterial Streets : asphalt concrete
- Collector Streets : asphalt concrete
- Major Local Streets : asphalt concrete
- Minor Local Streets : gravel

Design Sections

The road on the west side (Sections C1-1～C1-3) which is a part of C-1 is excluded from the discussion in this Chapter since it has already been paved.

The sections with high traffic volume or relatively weak roadbed soil of each class of street are selected for design section, as follows:

- Arterial Street : Section C2-3 (high traffic volume in C-2) and
  Section R5-2 (high traffic volume in R-5)

- Collector Street : Section CR1 (high traffic volume) and
  Section CR3 (low roadbed CBR)
- Major Local Street : Section L(I)1 (high traffic volume)
- Minor Local Street : not specified

(2) Methodology

Pavement design is carried out based on "AASHTO Guide for Design of Pavement Structures 1993" (AASHTO Guide).

Asphalt Pavement

The AASHTO Guide gives the basic design equation for flexible pavement (asphalt pavement) as follows:

Basic Design Equation for Flexible Pavement

$$\log_{10}(W_{18}) = Z_R \times S_0 + 9.36 \times \log_{10}(SN + 1) - 0.20 + \frac{\log_{10}\left(\frac{\triangle PSI}{4.2 - 1.5}\right)}{0.40 + \frac{1094}{(SN+1)^{5.19}}} + 2.32 \times \log_{10}(M_R) - 8.07$$

where

W_{18}	=	predicted number of 18-kip equivalent single axle load (ESAL) applications,
Z_R	=	standard normal deviate corresponding to level of reliability,
S_o	=	combined standard error of the traffic prediction and performance prediction,
$\triangle PSI$	=	difference between the initial design serviceability index, p_o, and the design terminal serviceability index, p_t, and
M_R	=	resilient modulus of roadbed soil (psi).

SN is equal to the structural number indicative of the total pavement thickness required:

$$SN = a_1D_1 + a_2D_2m_2 + a_3D_3m_3$$

where

a_i	=	i^{th} layer coefficient,
D_i	=	i^{th} layer thickness (inches), and
m_i	=	i^{th} layer drainage coefficient.

i=1 : Surface Course
i=2 : Base Course
i=3 : Subbase Course

Gravel Pavement

The AASHTO Guide gives the design procedure with nomograph for the design of the aggregate surfaced roads based on the following inputs : (1) predicted number of 18-kip ESAL, W_{18}, (2) length of the seasons, (3) seasonal resilient moduli of roadbed soil, M_R, (4) elastic modulus of aggregate base layer, E_{BS}, (5) elastic modulus of aggregate subbase layer, E_{SB}, (6) design serviceability loss, $\triangle PSI$, (7) allowable rutting, RD and (8) aggregate loss, GL. To facilitate the design, the AASHTO Guide provides the design catalog that may be used for the design of low-volume roads. The catalog shows the recommended aggregate base thickness, for various ranges of three factors: the relative quality of roadbed soil, traffic level and U.S. Climate Region*. The design catalog is applied to the pavement design in this Study.

* The United States are divided into six climate regions depending on the meteorological characteristics.

(3) Design Inputs

Performance Period

This refers to the period of time that an initial pavement structure will last before it needs rehabilitation.

For asphalt pavement, the performance period is set at 10 years, expecting that some type of rehabilitation or resurfacing is carried out within 10 years, while for gravel pavement, the performance period is assumed to be 3 years. The opening year is assumed to be 2012. Accordingly, the performance period is as follows:

- asphalt pavement : 10 years from 2012 to 2021

- gravel pavement : 3 years from 2012 to 2014

Traffic

The traffic load is expressed by cumulative number of 18-kip equivalent single axle load (ESAL) applications (w_{18}) during the performance period in the design lane. w_{18} is considered to be half of two-directional 18-kip ESAL applications in case of 2-lane road.

w_{18} is calculated based on the forecast future truck volume considering that other types of vehicles have little effect due to light axle load comparing with that of trucks. The cumulative number of trucks during the performance period is given in Table 1.

Table 1 Cumulative Number of Trucks during the Performance Period

Arterial Street (Section C2-3)		Arterial Street (Section R5-2)
Year	Number of Trucks	Number of Trucks
2012	2,439 /day x 365 days	3,005 /day x 365 days
2013	3,014 /day x 365 days	3,691 /day x 365 days
2014	3,723 /day x 365 days	4,533 /day x 365 days
2015	4,599 /day x 365 days	5,568 /day x 365 days
2016	4,970 /day x 365 days	5,679 /day x 365 days
2017	5,371 /day x 365 days	5,793 /day x 365 days
2018	5,804 /day x 365 days	5,908 /day x 365 days
2019	6,272 /day x 365 days	6,026 /day x 365 days
2020	6,777 /day x 365 days	6,147 /day x 365 days
2021	7,324 /day x 365 days	6,270 /day x 365 days
Total	50,293 /day x 365 days = 18,357,000	52,620 /day x 365 days = 19,206,000

Collector Street (Section CR1)		Collector Street (Section CR3)
Year	Number of Trucks	Number of Trucks
2012	1,595 /day x 365 days	930 /day x 365 days
2013	1,774 /day x 365 days	1,035 /day x 365 days
2014	1,973 /day x 365 days	1,151 /day x 365 days
2015	2,194 /day x 365 days	1,280 /day x 365 days
2016	2,364 /day x 365 days	1,379 /day x 365 days
2017	2,546 /day x 365 days	1,486 /day x 365 days
2018	2,743 /day x 365 days	1,600 /day x 365 days
2019	2,955 /day x 365 days	1,724 /day x 365 days
2020	3,183 /day x 365 days	1,857 /day x 365 days
2021	3,429 /day x 365 days	2,001 /day x 365 days
Total	24,756 /day x 365 days = 9,036,000	14,443 /day x 365 days = 5,272,000

Major Local Street (Section L(I)1)	
Year	Number of Trucks
2012	688 /day x 365 days
2013	765 /day x 365 days
2014	851 /day x 365 days
2015	946 /day x 365 days
2016	1,019 /day x 365 days
2017	1,098 /day x 365 days
2018	1,183 /day x 365 days
2019	1,274 /day x 365 days
2020	1,373 /day x 365 days
2021	1,479 /day x 365 days
Total	10,676 /day x 365 days = 3,897,000

Minor Local Street	
Year	Number of Trucks
2012	83 /day x 365 days
2013	92 /day x 365 days
2014	102 /day x 365 days
Total	277 /day x 365 days = 101,000

Note : Arterial, Collector and Major Local Streets : see Section 17.4.4.
Minor Local Street : Truck volume in 2009 on Minor Local Street is assumed to be 60/day, somewhat less than that on Major Local Streets which varies from 45 to 114/day except on L(I)1 and L(I)2. Annual growth rate is assumed to be 11.2 %, both for Major and Minor Local Streets.

The truck volume is converted to 18-kip ESAL, based on the axle load distribution and the axle load equivalency factor, which is given to each axle load in Appendix D of the AASHTO Guide. The axe load distribution is assumed as shown in Table 2.

Table 2 Assumption of Axle Load Distribution

Truck Type and Total Weight	Distribution of Axle Loads	% Share		
		Arterial Street	Collector Street	Minor Street
Truck (5.0 ton or less)	1.0 ton (S)+ 4.0 ton (S)	30%	40%	40%
Truck (9.0 ton)	1.8 ton (S)+ 7.2 ton (S)	25%	30%	30%
Truck (18.0 ton)	3.6 ton (S)+14.4 ton (T)	20%	10%	20%
Semi-trailer (18.0 ton)	3.6 ton (S)+14.4 ton (T)	10%	10%	10%

Trailer (32.4 ton)	3.6 ton (S)+ 9.6 ton (S)+19.2 ton (T)	10%	10%	-
Double-trailer (61.2 ton)	3.6 ton (S)+ 9.6 ton (S)+19.2 ton (T) +9.6 ton (S)+19.2 ton (T)	5%	-	-

Note : S=Single Axle, T=Tandem Axle

Based on the above distribution, 18-kip ESAL of each axle is obtained from Appendix D of the AASHTO Guide and taking into account the shares of trucks by type, the average number of 18-kip ESALs per truck (Truck Load Factor) is calculated as shown in Table 3.

Table 3 Truck Load Factor

Arterial Streets (p_t=2.5, SN=4)

Vehicle Type	Share	Axle Load - 1 / Axle Load - 4				Axle Load - 2 / Axle Load - 5				Axle Load - 3				Σ ALEF	Σ ALEF x Share
		*	ton	kips	ALEF	*	ton	kips	ALEF	*	ton	kips	ALEF		
Truck (5.0 ton or less)	30%	S	1.0	2.2	0.000	S	4.0	8.8	0.065			-		0.065	0.020
Truck (9.0 ton)	25%	S	1.8	4.0	0.003	S	7.2	15.9	0.632			-		0.635	0.159
Truck (18.0 ton)	20%	S	3.6	7.9	0.040	T	14.4	31.7	0.858			-		0.898	0.180
Semi-trailer (18.0 ton)	10%	S	3.6	7.9	0.040	T	14.4	31.7	0.858			-		0.898	0.090
Trailer (32.4 ton)	10%	S	3.6	7.9	0.040	S	9.6	21.1	1.811	T	19.2	42.3	2.498	4.349	0.435
Double-trailer (61.2 ton)	5%	S S	3.6 9.6	7.9 21.1	0.040 1.811	S T	9.6 19.2	21.1 42.3	1.811 2.498	T	19.2	42.3	2.498	8.658	0.433
													Truck Load Factor		1.317

Collector Streets (p_t=2.5, SN=3)

Vehicle Type	Share	Axle Load - 1 / Axle Load - 4				Axle Load - 2 / Axle Load - 5				Axle Load - 3				Σ ALEF	Σ ALEF x Share
		*	ton	kips	ALEF	*	ton	kips	ALEF	*	ton	kips	ALEF		
Truck (5.0 ton or less)	40%	S	1.0	2.2	0.001	S	4.0	8.8	0.078			-		0.079	0.032
Truck (9.0 ton)	30%	S	1.8	4.0	0.004	S	7.2	15.9	0.634			-		0.638	0.191
Truck (18.0 ton)	10%	S	3.6	7.9	0.049	T	14.4	31.7	0.861			-		0.910	0.091
Semi-trailer (18.0 ton)	10%	S	3.6	7.9	0.049	T	14.4	31.7	0.861			-		0.910	0.091
Trailer (32.4 ton)	10%	S	3.6	7.9	0.049	S	9.6	21.1	1.864	T	19.2	42.3	2.565	4.478	0.448
													Truck Load Factor		0.853

Local Streets (p_t=2.0, SN=2)

Vehicle Type	Share	Axle Load - 1 / Axle Load - 4				Axle Load - 2 / Axle Load - 5				Axle Load - 3				Σ ALEF	Σ ALEF x Share
		*	ton	kips	ALEF	*	ton	kips	ALEF	*	ton	kips	ALEF		
Truck (5.0 ton or less)	40%	S	1.0	2.2	0.000	S	4.0	8.8	0.055			-		0.055	0.022
Truck (9.0 ton)	30%	S	1.8	4.0	0.003	S	7.2	15.9	0.585			-		0.588	0.176
Truck (18.0 ton)	20%	S	3.6	7.9	0.034	T	14.4	31.7	0.793			-		0.827	0.165
Semi-trailer (18.0 ton)	10%	S	3.6	7.9	0.034	T	14.4	31.7	0.793			-		0.827	0.083
													Truck Load Factor		0.446

ALEF : Axle Load Equivalency Factor
* S : Single Axle T : Tandem Axle

The traffic load (w_{18}) is expressed by cumulative number of 18-kip equivalent single axle load (ESAL) applications, which is calculated by the following equation:

$$w_{18} = V_{TR} \times TLF \times D_D \times D_L$$

where
V_{TR} = Cumulative two-directional number of trucks,
TLF = Truck load factor,
D_D = Directional distribution factor (0.5 for 2-lane street and 1.0 for 1-lane strret), and
D_L = Lane distribution factor, expressed as a ratio, that accounts for distribution of traffic when two or more lanes are available in one direction.

The traffic load (w_{18}) of each section is calculated as shown in Table 4.

Table 4 Traffic Load

	V_{TR}	TLF	D_D	D_L	w_{18}
Arterial (C2-3)	18,357,000	1.317 *	0.5 (2-lane)	1.0	12,088,000
Arterial (R5-2)	19,206,000	1.317 *	0.5 (2-lane)	1.0	12,647,000

Collector (CR1)	9,036,000	0.853 **	0.5 (2-lane)	1.0	3,854,000
Collector (CR3)	5,272,000	0.853 **	0.5 (2-lane)	1.0	2,249,000
Major Local (L(I)1)	3,897,000	0.446 ***	0.5 (2-lane)	1.0	869,000
Minor Local	101,000	0.446 ***	1.0 (1-lane)	1.0	45,000

TLF * : in case of p_t=2.5 and SN=4, ** : in case of p_t=2.5 and SN=3, *** : in case of p_t=2.0 and SN=2

Reliability

Reliability is a means of incorporating some degree of certainty into the design process to ensure that the various design alternatives will last the analysis period. The reliability design factor accounts for chance variations in both traffic prediction (w_{18}) and the performance prediction (W_{18}), and therefore provides a predetermined level of assurance (R) that pavement sections will survive the period for which they were designed.

The AASHTO Guide suggests the level of reliability (R) for urban principal arterials, collectors and local to be 80–99%, 80–95% and 50–80% respectively. In this Study, R is set at 80%, 80% and 60% for arterial, collector and local streets respectively. The AASHTO Guide gives the standard normal deviate (Z_R) values corresponding to selected levels of reliability as shown in Table 5 and suggests the combined standard error of the traffic prediction and performance prediction (S_o) of 0.45 for flexible pavement based on the AASHO Road Test.

Table 5 Standard Normal Deviate (Z_R) Values Corresponding to Selected Levels of Reliability

Reliability, R (%)	Standard Normal Deviate, Z_R	Reliability, R (%)	Standard Normal Deviate, Z_R	Reliability, R (%)	Standard Normal Deviate, Z_R
50	0	90	-1.282	96	-1.751
60	-0.253	91	-1.340	97	-1.881
70	-0.524	92	-1.405	98	-2.054
75	-0.674	93	-1.476	99	-2.327
80	-0.841	94	-1.555	99.9	-3.090
85	-1.037	95	-1.645	99.99	-3.750

Source : The AASHTO Guide

Following the AASHTO Guide suggestion, R, Z_R and S_o are set as shown in Table 6.

Table 6 Reliability Related Values

	Level of Reliability (R)	Standard Normal Deviate (Z_R)	Combined standard error of the traffic prediction and performance prediction (S_o)
Arterial Streets	80 %	-0.841	0.45
Collector Streets	80 %	-0.841	0.45
Local Streets	60 %	-0.253	0.45

Performance Criteria

Pavement performance is represented by the serviceability history of a pavement. The serviceability of a pavement is defined as its ability to serve the type of traffic (automobiles and trucks) which use the facility. The primary measure of serviceability is the Present Serviceability Index (PSI), which ranges from 0 (impossible road) to 5 (perfect road).

Selection of the lowest allowable PSI or *terminal serviceable index* (p_t) is based on the lowest index that will tolerated before rehabilitation, resurfacing, or reconstruction becomes necessary. An index of 2.5 or higher is suggested by the AASHTO Guide for design of major highways and 2.0 for highways with lesser traffic volumes.

The *initial serviceability index* (p_o) is the value immediately after construction. p_o observed at the AASHO Road Test was 4.2 for flexible pavement.

The total change in serviceability index is expressed by $\triangle PSI = p_o - p_t$

In this design, p_o and p_t are established as shown in Table 7.

Table 7 Performance Criteria

	Initial Serviceability Index (p_o)	Terminal Serviceability Index (p_t)	Change in Serviceability Index (△PSI)
Arterial Streets	4.2	2.5	1.7
Collector Streets	4.2	2.5	1.7
Local Streets	4.2	2.0	2.2

Roadbed soil

The resilient modulus (M_R) is used to characterize roadbed soil property. The AASHTO Guide introduces the equation estimating M_R from CBR or R-value, as follows:

M_R (psi)=1,500 x CBR

This equation, which is considered reasonable with a soaked CBR of 10 or less, is used in this Study limiting to CBR of 10 (regarding 10 in case of CBR more than 10).

According to the CBR test results, the CBRs of all design sections are 10 or more, except for Collector Road CR3 where the CBR is 7. Accordingly, the resilient moduli are estimated to be 15,000 psi for all design sections, except for Collector Road CR3 where the resilient modulus is 10,500 psi.

Pavement Structure

Structural Layer Coefficient

The pavement strength is expressed by the structural number (SN) which is indicative of the total pavement thickness required. In order to convert actual layer thickness into SN, the structural layer coefficients (a_i) are required. The AASHTO Guide provides the charts that may be used to estimate the structural layer coefficients.

Based on the charts, the following structural layer coefficients are assumed in this Study :

- Asphalt concrete surface course : a_1 = 0.390 (in case of E_{AC}^*=350,000 psi)
- Granular base course : a_2 = 0.135 (in case of CBR=80)
- Granular subbase course : a_3 = 0.094 (incase of CBR=20)

* E_{AC} : elastic modulus of asphalt concrete at 68°F

Drainage Coefficient

The structural layer coefficients are modified considering the effects of certain levels of drainage on predicted pavement performance. The factor for modifying the structural layer coefficient is referred to as m_i value. The recommended m_i values are given in the AASHTO Guide as shown in Table 8.

Table 8 Recommended m_i values for Modifying Structural Layer Coefficients of Untreated Base and Subbase Materials in Flexible Pavements

Quality of Drainage		Percent of Time Pavement Structure is Exposed to Moisture Levels Approaching Saturation			
		Less than 1 %	1 – 5 %	5 – 25 %	Greater than 25 %
Excellent	(water removed within 2 hours)	1.25 – 1.20	1.35 – 1.30	1.30 – 1.20	1.20
Good	(water removed within 1 day)	1.20 – 1.15	1.25 – 1.15	1.15 – 1.00	1.00
Fair	(water removed within 1 week)	1.15 – 1.10	1.15 – 1.05	1.00 – 0.80	0.80
Poor	(water removed within 1 month)	1.10 – 1.00	1.05 – 0.80	0.80 – 0.60	0.60
Very poor	(water will not drain)	1.00 – 0.90	0.95 – 0.75	0.75 – 0.40	0.40

Source : The AASHTO Guide

In this Study, m_2 and m_3 are estimated at 1.00 assuming that the quality of drainage is fair and that the pavement structure is exposed to moisture levels approaching saturation during 5 % of the year.

Summary

Table 9 summarizes the design inputs.

Table 9 Summary of Design Inputs

Item	Design Conditions/Assumptions	Arterial Street (C2-3)	Arterial Street (R5-2)	Collector Street (CR1)	Collector Street (CR3)	Major Local Street (L(I)1)	Minor Local Street
Performance Period	10 years, except for Minor Local Street (3 years)	10 years (2012-2021)	10 years (2012-2021)	10 years (2012-2021)	10 years (2012-2021)	10 years (2012-2021)	3 years (2012-2014)
Traffic	Directional Distribution Factor (D_D) = 0.5 Truck load factor = 1.317 (Arterial Street) 0.853 (Collector Street) 0.446 (Local Strret)	w_{18} =12,088,000	w_{18} =12,647,000	w_{18} =3,854,000	w_{18} =2,249,000	w_{18} =869,000	w_{18} =45,000
Reliability	Level of Reliability (R) - Standard Normal Deviate (Z_R) - Combined Standard Error of the Traffic Prediction and Performance Prediction (S_o)	R=80 % Z_R=-0.841 S_o=0.45	R=80 % Z_R=-0.841 S_o=0.45	R=80 % Z_R=-0.841 S_o=0.45	R=80 % Z_R=-0.841 S_o=0.45	R=60 % Z_R=-0.253 S_o=0.45	-
Performance Criteria	Initial Design Serviceability Index (p_o) Design Terminal Serviceability Index (p_t) - Deference between p_o and p_t (△PSI)	po=4.2 pt=2.5 △PSI=1.7	po=4.2 pt=2.5 △PSI=1.7	po=4.2 pt=2.5 △PSI=1.7	po=4.2 pt=2.5 △PSI=1.7	po=4.2 pt=2.0 △PSI=2.2	-
Roadbed Soil	Resilient Modulus (M_R) = 1,500 x CBR (CBR<10) = 15,000 (CBR≥10)	M_R=15,000 (CBR≥10)	M_R=15,000 (CBR≥10)	M_R=15,000 (CBR≥10)	M_R=10,500 (CBR=7)	M_R=15,000 (CBR≥10)	MR=10,500 ～ 15,000
Structural Layer Coefficient	Asphalt Concrete Surface Course (a_1) = 0.390 (E_{AC}=350,000 psi) Granular Base Course (a_2) = 0.135 (CBR=80) Granular Subbase Course (a_3) = 0.094 (CBR=20)	a_1=0.390 a_2=0.135 a_3=0.094	a_1=0.390 a_2=0.135 a_3=0.094	a_1=0.390 a_2=0.135 a_3=0.094	a_1=0.390 a_2=0.135 a_3=0.094	a_1=0.390 a_2=0.135 a_3=0.094	a_2=0.135 a_3=0.094
Drainage	Quality of drainage is fair (water removed within 1 week). Pavement structure is exposed to moisture levels approaching saturation during 5% of the year. - Drainage Coefficient of Granular Base Course (m_2) - Drainage Coefficient of Granular Subbase Course (m_3)	m_2=1.0 m_3=1.0	m_2=1.0 m_3=1.0	m_2=1.0 m_3=1.0	m_2=1.0 m_3=1.0	m_2=1.0 m_3=1.0	m_2=1.0 m_3=1.0

(4) Flexible Pavement (Asphalt Pavement) Design

Procedure

The pavement structural design is carried out in the following procedures:

① Determine the design inputs, including
- W_{18} (predicted number of 18-kip ESAL applications,
- Z_R (standard normal deviate),
- S_o (combined standard error of the traffic prediction and performance prediction),
- △PSI (difference between the initial design serviceability index, po, and the design terminal serviceability index, pt, and
- M_R (roadbed soil resilient modulus in psi).

② Determine the design structural number (SN) required applying the Basic Design Equation for Flexible Pavement (shown in (2) above).
The AASHTO Guide gives the nomograph for determining SN.

③ Select the materials and thicknesses of layers composing the pavement structure, including asphalt concrete surface course, base course and subbase course. Then, calculate the structural number and check it against the required SN determined in ② above.

Required Structural Number

Table 10 shows the required structural number.

Table 10 Required Structural Number

Road Class		Arterial Street		Collector Street		Major Local
Section		C2-3	R5-2	CR1	CR3	L(I)1
Inputs	W_{18}	12,088,000	12,647,000	3,854,000	2,249,000	869,000
	Z_R	-0.841	-0.841	-0.841	-0.841	-0.253
	S_o	0.45	0.45	0.45	0.45	0.45
	△PSI	1.7	1.7	1.7	1.7	2.2
	M_R	15,000	15,000	15,000	10,500	15,000
Required SN		**3.724**	**3.751**	**3.087**	**3.238**	**2.148**

Selection of Pavement Materials

The following materials are selected.

- Surface course : dense-graded asphalt concrete with elastic modulus (E_{AC}) of 350,000 psi at 68° F
- Base Course : mechanically stabilized crushed stone with CBR=80
- Subbase Course : crusher-run with CBR=20

Structural Number (SN)

The structural number (SN) is calculated by the following equation :

$SN = a_1D_1 + a_2D_2m_2 + a_3D_3m_3$

Table 11 shows the SNs of various thicknesses of pavement.

Table 11 Structural Numbers of Various Thicknesses of Pavement

AC Surface Course (a_1=0.390)

Thickness (cm) t_1	a_1	D_1		$a_1 \cdot D_1$
5	0.390	1.969		0.768
10	0.390	3.937		1.535

Base Cource (a_2=0.135, m_2=1.0)

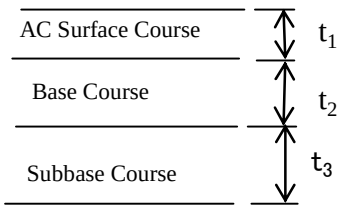
Thickness (cm) t_2	a_2	D_2	m_2	$a_2 \cdot D_2 \cdot m_2$
10	0.135	3.937	1.0	0.531
15	0.135	5.906	1.0	0.797
20	0.135	7.874	1.0	1.063

Subbase Cource (a_3=0.094, m3=1.0)

Thickness (cm) t_3	a_3	D_3	m_3	$a_3 \cdot D_3 \cdot m_3$
15	0.094	5.906	1.0	0.555
20	0.094	7.874	1.0	0.740
25	0.094	9.843	1.0	0.925
30	0.094	11.811	1.0	1.110
35	0.094	13.780	1.0	1.295

Combination

Thickness (cm) t_1-t_2-t_3	SN
5-10-15	0.768 + 0.531 + 0.555 = 1.854
5-10-20	0.768 + 0.531 + 0.740 = 2.039
5-15-25	0.768 + 0.797 + 0.925 = 2.490
5-15-30	0.768 + 0.797 + 1.110 = 2.675
5-20-35	0.768 + 1.063 + 1.295 = 3.126
10-10-15	1.535 + 0.531 + 0.555 = 2.621
10-10-20	1.535 + 0.531 + 0.740 = 2.806
10-15-25	1.535 + 0.797 + 0.925 = 3.257
10-15-30	1.535 + 0.797 + 1.110 = 3.442
10-20-30	1.535 + 1.063 + 1.110 = 3.708
10-20-35	1.535 + 1.063 + 1.295 = 3.893

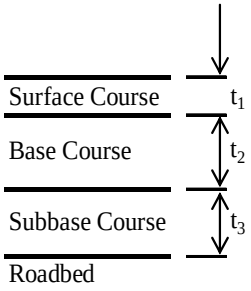


Selection of Layer Thicknesses

Table 12 shows the thicknesses selected.

Table 12 Layer Thicknesses Selected

		Arterial Street (Section C2-3 & Section R5-2)	Collector Street (Section CR1 & Section CR3)	Major Local St. (Section L(I)1)
Thickness	Surface Course (t_1)	10 cm	10 cm	5 cm
	Base Course (t_2)	20 cm	15 cm	15 cm
	Subbase Course (t_3)	35 cm	25 cm	25 cm
	Total	65 cm	50 cm	45 cm
Structural Number (SN)		3.893	3.257	2.490
Required Structural Number		3.724 (C2-3) 3.751 (R5-2)	3.087 (CR1) 3.238 (CR3)	2.148



The structural number (SN) is superior to the required.

(5) Aggregate-Surfaced Road (Gravel Pavement) Design

The AASHTO Guide provides the design catalog that may be used for the design of low-volume roads, as shown in Table 13.

Table 13 Aggregate Surfaced Road Design Catalog : Recommended Aggregate Base Thickness (in Inches) for the Six U.S. Climate Regions, Five Relative Qualities of Roadbed Soil and Three Levels of Traffic

Relative Quality of Roadbed Soil	Traffic Level	U.S. Climate Region					
		I	II	III	IV	V	VI
Very good	High	8	10	15	7	9	15
	Medium	6	8	11	5	7	11
	Low	4	4	6	4	4	6
Good	High	11	12	17	10	11	17
	Medium	8	9	12	7	9	12
	Low	4	5	7	4	5	7
Fair	High	13	14	17	12	13	17
	Medium	11	11	12	10	10	12
	Low	6	6	7	5	5	7
Poor	High	**	**	**	**	**	**
	Medium	**	**	**	15	15	**
	Low	9	10	9	8	8	9
Very poor	High	**	**	**	**	**	**
	Medium	**	**	**	**	**	**
	Low	11	11	10	8	8	9

** Higher type pavement design recommended.

Source : AASHTO Guide

Relative quality of roadbed soil, traffic level and U.S. Climate Region in Table 13 are given in Table 14.

Table 14 Ranges of Relative quality of roadbed soil, traffic level and U.S. Climate Region in Table 13

U.S. Climate Region	Relative Quality of Roadbed Soil (Effective Resilient Modulus in case of U.S. Climate Region IV)	Traffic Level (18-kip ESAL applications)
I : Wet, no freeze		
II : Wet, freeze-thaw cycling	Very Poor : 3,200 psi	High : 60,000 to 100,000
III : Wet, hard-freeze, spring thaw	Poor : 4,100 psi	Medium : 30,000 to 60,000
IV : Dry, no freeze	Fair : 5,600 psi	Low : 10,000 to 30,000
V : Dry, freeze-thaw cycling	Good : 7,900 psi	
VI : Dry, hard-freeze, spring thaw	Very Good : 11,700 psi	

The following conditions are considered to be applicable to Minor Local Streets:

- 'U.S. Climate Region IV' (dry, no freeze),
- relative quality of roadbed soil : 'Good' (resilient modulus 10,500 – 15,000 psi), and
- traffic level : 'Medium' (18-kip ESAL 45,000),

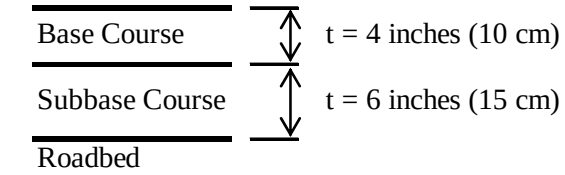
Recommended aggregate base thickness corresponding to the above conditions is 7 inches according to Table 13.

The AASHTO Guide provides the chart to convert a portion of the aggregate base layer thickness to an equivalent thickness of subbase. Out of 7 inches of required base thickness, 3 inches are converted to the equivalent thickness of subbase based on the said chart.

Conditions : ${}^{D}BS_i$ (thickness of base course required) = 7 inches,
${}^{D}BS_f$ (final thickness of base course) = 4 inches,
${}^{D}BS_i$-${}^{D}BS_f$ (reduction in base thickness) = 3 inches
E_{SB} (resilient modulus of subbase course material) = 13,000 psi, and
E_{BS} (resilient modulus of base course material) = 30,000 psi

Solution : D_{SB} (required subbase thickness corresponding to the reduction in base thickness, 3 inches) is given as 6 inches.

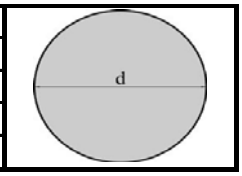
The final layer thickness is as follows:



APPENDIX 12 DRAINAGE DESIGN IN CCD (UNDER CHAPTER 17)

1) Discharge Capacity of Pipe Drain (Dia. 600mm)

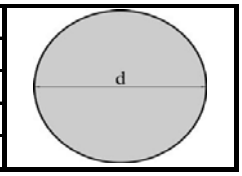
Input Data		
diameter		
d	(cm)	60.0
roughness		
n		0.013



grade	section	hydraulic mean depth	Manning's Formula		
			velocity	discharge	torerable discharge
I	A	R	V	Q	Q80
(%)	(m2)	(cm)	(m/sec)	(litter/sec)	(litter/sec)
0.200%	0.28274	15.00000	0.97118	274.6	219.7
0.400%	0.28274	15.00000	1.37345	388.3	310.7
0.600%	0.28274	15.00000	1.68213	475.6	380.5
0.800%	0.28274	15.00000	1.94236	549.2	439.4
1.000%	0.28274	15.00000	2.17162	614.0	491.2
1.200%	0.28274	15.00000	2.37889	672.6	538.1
1.400%	0.28274	15.00000	2.56950	726.5	581.2
1.600%	0.28274	15.00000	2.74691	776.7	621.3
1.800%	0.28274	15.00000	2.91354	823.8	659.0
2.000%	0.28274	15.00000	3.07114	868.3	694.7

2) Discharge Capacity of Pipe Drain (Dia. 800mm)

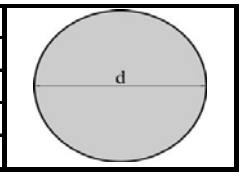
Input Data		
diameter		
d	(cm)	80.0
roughness		
n		0.013



grade	section	hydraulic mean depth	Manning's Formula		
			velocity	discharge	torerable discharge
I	A	R	V	Q	Q80
(%)	(m2)	(cm)	(m/sec)	(m3/sec)	(m3/sec)
0.200%	0.50265	20.00000	1.17650	591.4	473.1
0.400%	0.50265	20.00000	1.66382	836.3	669.1
0.600%	0.50265	20.00000	2.03776	1,024.3	819.4
0.800%	0.50265	20.00000	2.35300	1,182.7	946.2
1.000%	0.50265	20.00000	2.63073	1,322.4	1,057.9
1.200%	0.50265	20.00000	2.88182	1,448.6	1,158.8
1.400%	0.50265	20.00000	3.11272	1,564.6	1,251.7
1.600%	0.50265	20.00000	3.32764	1,672.7	1,338.1
1.800%	0.50265	20.00000	3.52950	1,774.1	1,419.3
2.000%	0.50265	20.00000	3.72042	1,870.1	1,496.1

3) Discharge Capacity of Pipe Drain (Dia. 1000mm)

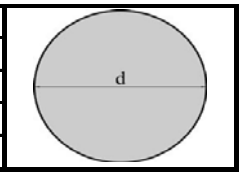
Input Data		
diameter		
d	(cm)	100.0
roughness		
n		0.013



grade	section	hydraulic mean depth	Manning's Formula		
			velocity	discharge	torerable discharge
I	A	R	V	Q	Q80
(%)	(m2)	(cm)	(m/sec)	(m3/sec)	(m3/sec)
0.200%	0.78540	25.00000	1.36521	1,072.2	857.8
0.400%	0.78540	25.00000	1.93069	1,516.4	1,213.1
0.600%	0.78540	25.00000	2.36461	1,857.2	1,485.7
0.800%	0.78540	25.00000	2.73041	2,144.5	1,715.6
1.000%	0.78540	25.00000	3.05269	2,397.6	1,918.1
1.200%	0.78540	25.00000	3.34406	2,626.4	2,101.1
1.400%	0.78540	25.00000	3.61200	2,836.9	2,269.5
1.600%	0.78540	25.00000	3.86139	3,032.7	2,426.2
1.800%	0.78540	25.00000	4.09562	3,216.7	2,573.4
2.000%	0.78540	25.00000	4.31716	3,390.7	2,712.6

4) Discharge Capacity of Pipe Drain (Dia. 1200mm)

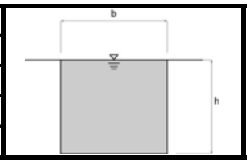
Input Data		
diameter		
d	(cm)	120.0
roughness		
n		0.013



grade	section	hydraulic mean depth	Manning's Formula		
			velocity	discharge	torerable discharge
I	A	R	V	Q	Q80
(%)	(m2)	(cm)	(m/sec)	(m3/sec)	(m3/sec)
0.200%	1.13097	30.00000	1.54165	1,743.6	1,394.9
0.400%	1.13097	30.00000	2.18022	2,465.8	1,972.6
0.600%	1.13097	30.00000	2.67022	3,019.9	2,416.0
0.800%	1.13097	30.00000	3.08330	3,487.1	2,789.7
1.000%	1.13097	30.00000	3.44723	3,898.7	3,119.0
1.200%	1.13097	30.00000	3.77626	4,270.8	3,416.7
1.400%	1.13097	30.00000	4.07882	4,613.0	3,690.4
1.600%	1.13097	30.00000	4.36044	4,931.5	3,945.2
1.800%	1.13097	30.00000	4.62495	5,230.7	4,184.6
2.000%	1.13097	30.00000	4.87513	5,513.6	4,410.9

5) Discharge Capacity of Pipe Drain (Open Channel 400mm x 400mm)

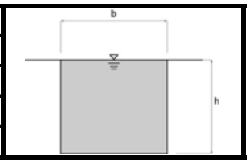
Input Data		
width	b(cm)	40.0
height	h(cm)	40.0
roughness		
n		0.015



grade	section	hydraulic mean depth	Manning's Formula		
			velocity	discharge	torerable discharge
I	A	R	V	Q	Q80
(%)	(m2)	(cm)	(m/sec)	(litter/sec)	(litter/sec)
0.200%	0.16000	13.33333	0.77813	124.5	99.6
0.400%	0.16000	13.33333	1.10044	176.1	140.9
0.600%	0.16000	13.33333	1.34775	215.6	172.5
0.800%	0.16000	13.33333	1.55625	249.0	199.2
1.000%	0.16000	13.33333	1.73994	278.4	222.7
1.200%	0.16000	13.33333	1.90601	305.0	244.0
1.400%	0.16000	13.33333	2.05873	329.4	263.5
1.600%	0.16000	13.33333	2.20087	352.1	281.7
1.800%	0.16000	13.33333	2.33438	373.5	298.8
2.000%	0.16000	13.33333	2.46065	393.7	315.0

6) Discharge Capacity of Pipe Drain (Open Channel 600mm x 600mm)

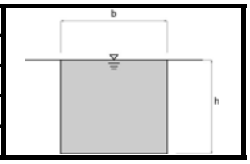
Input Data		
width	b(cm)	60.0
height	h(cm)	60.0
roughness		
n		0.015



grade	section	hydraulic mean depth	Manning's Formula		
			velocity	discharge	torerable discharge
I	A	R	V	Q	Q80
(%)	(m2)	(cm)	(m/sec)	(litter/sec)	(litter/sec)
0.200%	0.36000	20.00000	1.01963	367.1	293.7
0.400%	0.36000	20.00000	1.44198	519.1	415.3
0.600%	0.36000	20.00000	1.76606	635.8	508.6
0.800%	0.36000	20.00000	2.03927	734.1	587.3
1.000%	0.36000	20.00000	2.27997	820.8	656.6
1.200%	0.36000	20.00000	2.49758	899.1	719.3
1.400%	0.36000	20.00000	2.69769	971.2	776.9
1.600%	0.36000	20.00000	2.88396	1,038.2	830.6
1.800%	0.36000	20.00000	3.05890	1,101.2	881.0
2.000%	0.36000	20.00000	3.22436	1,160.8	928.6

7) Discharge Capacity of Pipe Drain (Open Channel 800mm x 800mm)

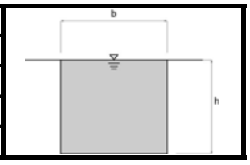
Input Data		
width	b(cm)	80.0
height	h(cm)	80.0
roughness		
n		0.015



grade	section	hydraulic mean depth	Manning's Formula		
			velocity	discharge	torerable discharge
I	A	R	V	Q	Q80
(%)	(m2)	(cm)	(m/sec)	(litter/sec)	(litter/sec)
0.200%	0.64000	26.66667	1.23520	790.5	632.4
0.400%	0.64000	26.66667	1.74683	1,118.0	894.4
0.600%	0.64000	26.66667	2.13942	1,369.2	1,095.4
0.800%	0.64000	26.66667	2.47039	1,581.1	1,264.8
1.000%	0.64000	26.66667	2.76198	1,767.7	1,414.1
1.200%	0.64000	26.66667	3.02560	1,936.4	1,549.1
1.400%	0.64000	26.66667	3.26802	2,091.5	1,673.2
1.600%	0.64000	26.66667	3.49366	2,235.9	1,788.8
1.800%	0.64000	26.66667	3.70559	2,371.6	1,897.3
2.000%	0.64000	26.66667	3.90604	2,499.9	1,999.9

8) Discharge Capacity of Pipe Drain (Open Channel 1000mm x 1000mm)

Input Data		
width	b(cm)	100.0
height	h(cm)	100.0
roughness		
n		0.015



grade	section	hydraulic mean depth	Manning's Formula		
			velocity	discharge	torerable discharge
I	A	R	V	Q	Q80
(%)	(m2)	(cm)	(m/sec)	(litter/sec)	(litter/sec)
0.200%	1.00000	33.33333	1.43332	1,433.3	1,146.7
0.400%	1.00000	33.33333	2.02702	2,027.0	1,621.6
0.600%	1.00000	33.33333	2.48258	2,482.6	1,986.1
0.800%	1.00000	33.33333	2.86664	2,866.6	2,293.3
1.000%	1.00000	33.33333	3.20500	3,205.0	2,564.0
1.200%	1.00000	33.33333	3.51090	3,510.9	2,808.7
1.400%	1.00000	33.33333	3.79221	3,792.2	3,033.8
1.600%	1.00000	33.33333	4.05404	4,054.0	3,243.2
1.800%	1.00000	33.33333	4.29996	4,300.0	3,440.0
2.000%	1.00000	33.33333	4.53255	4,532.6	3,626.0

APPENDIX 13 PAVEMENT DESIGN OF URBAN STREETS IN SOUTHERN JUBA (UNDER CHAPTER 19)

(1) Methodology

Pavement design is carried out based on "AASHTO Guide for Design of Pavement Structures 1993" (AASHTO Guide).

The basic design equation for flexible pavement (asphalt pavement) is as follows:

Basic Design Equation for Flexible Pavement

$$\log_{10}(W_{18}) = Z_R \times S_0 + 9.36 \times \log_{10}(SN+1) - 0.20 + \frac{\log_{10}\left(\frac{\triangle PSI}{4.2-1.5}\right)}{0.40 + \frac{1094}{(SN+1)^{5.19}}} + 2.32 \times \log_{10}(M_R) - 8.07$$

where

W_{18}	=	predicted number of 18-kip equivalent single axle load (ESAL) applications,
Z_R	=	standard normal deviate corresponding to level of reliability,
S_o	=	combined standard error of the traffic prediction and performance prediction,
$\triangle PSI$	=	difference between the initial design serviceability index, p_o, and the design terminal serviceability index, p_t, and
M_R	=	resilient modulus of roadbed soil (psi).

SN is equal to the structural number indicative of the total pavement thickness required:

$$SN = a_1D_1 + a_2D_2m_2 + a_3D_3m_3$$

where

a_i	=	i^{th} layer coefficient,
D_i	=	i^{th} layer thickness (inches), and
m_i	=	i^{th} layer drainage coefficient.

i=1 : Surface Course
i=2 : Base Course
i=3 : Subbase Course

(2) Design Inputs

Performance Period

This refers to the period of time that an initial pavement structure will last before it needs rehabilitation. Expecting that some type of rehabilitation or resurfacing is carried out within 10years, the performance period is set at 10 years.

As per the construction schedule in the master plan, the performance period is assumed as shown in Table 1.

Table 1 Performance Periods

	Completion Year	Opening Year	Performance Period
C-2 (Southern Section)	2015	2016	10 years (2016-2025)
C-3 (Southern Section)	2015	2016	10 years (2016-2025)
Lologo Radial Road	2020	2021	10 years (2021-2030)
Nyakuron Radial Road	2020	2021	10 years (2021-2030)

Traffic

The traffic load is expressed by cumulative number of 18-kip equivalent single axle load (ESAL) applications (w_{18}) during the performance period in the design lane, which is given in the following equation:

$w_{18} = D_D \times D_L \times \hat{w}_{18}$

where
D_D = a directional distribution factor,
D_L = a lane distribution factor, expressed as a ratio, that accounts for distribution of traffic when two or more lanes are available in one direction, and
$\hat{w}_{18}$ = the cumulative number of two-directional 18-kip ESAL applications.

D_D is assumed to be 0.5. The AASHTO Guide gives D_L values which may be used as a guide, as shown in Table 2. In this Study, all roads are planned to be 2-lane roads in the initial stage (1 lane in one direction). Therefore, D_L is 1.0.

Table 2 Lane Distribution Factor (D_L)

Number of Lanes in Each Direction	Lane Distribution Factor (D_L)
1	1.00
2	0.80 – 1.00
3	0.60 – 0.80
4	0.50 – 0.75

$\hat{w}_{18}$ is calculated based on the forecast future truck volume considering that other types of vehicles have little effect due to light axle load comparing with that of trucks. The cumulative number of trucks during the performance period is given in Table 3.

Table 3 Cumulative Number of Trucks during the Performance Period

C-2 (Section 4)	
Year	Number of Trucks
2016	4,969 /day x 365 days
2017	5,370 /day x 365 days
2018	5,803 /day x 365 days
2019	6,271 /day x 365 days
2020	6,777 /day x 365 days
2021	7,324 /day x 365 days
2022	7,915 /day x 365 days
2023	8,553 /day x 365 days
2024	9,243 /day x 365 days
2025	9,989 /day x 365 days
Total	72,214 /day x 365 days = 26,358,000

C-3 (Section 2)	
Year	Number of Trucks
2016	1,556 /day x 365 days
2017	1,740 /day x 365 days
2018	1,946 /day x 365 days
2019	2,177 /day x 365 days
2020	2,434 /day x 365 days
2021	2,723 /day x 365 days
2022	3,045 /day x 365 days
2023	3,406 /day x 365 days
2024	3,809 /day x 365 days
2025	4,260 /day x 365 days
Total	27,096 /day x 365 days = 9,890,000

Lologo Radial Road	
Year	Number of Trucks
2021	3,251 /day x 365 days
2022	3,412 /day x 365 days
2023	3,580 /day x 365 days
2024	3,757 /day x 365 days
2025	3,943 /day x 365 days
2026	4,138 /day x 365 days
2027	4,342 /day x 365 days
2028	4,557 /day x 365 days
2029	4,782 /day x 365 days
2030	5,019 /day x 365 days
Total	40,781 /day x 365 days = 14,885,000

Nyakuron Radial Road	
Year	Number of Trucks
2021	2,167 /day x 365 days
2022	2,398 /day x 365 days
2023	2,653 /day x 365 days
2024	2,935 /day x 365 days
2025	3,247 /day x 365 days
2026	3,592 /day x 365 days
2027	3,974 /day x 365 days
2028	4,397 /day x 365 days
2029	4,864 /day x 365 days
2030	5,382 /day x 365 days
Total	35,609 /day x 365 days = 12,997,000

The truck volume is converted to 18-kip ESAL, based on the axle load distribution and the axle load equivalency factor, which is given to each axle load in Appendix D of the AASHTO Guide. The axe load distribution is assumed as shown in Table 4

Table 4 Assumption of Axle Load Distribution

Truck Type and Total Weight	Distribution of Axle Loads	% Share	
		C-2, C-3 (Arterial Street)	Lologo/Nyakuron Radial Road (Collector Street)
Truck (5.0 ton or less)	1.0 ton (S)+ 4.0 ton (S)	30 %	40 %
Truck (9.0 ton)	1.8 ton (S)+ 7.2 ton (S)	25 %	30 %
Truck (18.0 ton)	3.6 ton (S)+14.4 ton (T)	20 %	10 %
Semi-trailer (18.0 ton)	3.6 ton (S)+14.4 ton (T)	10 %	10 %
Trailer (32.4 ton)	3.6 ton (S)+ 9.6 ton (S)+19.2 ton (T)	10 %	10 %
Double-trailer (61.2 ton)	3.6 ton (S)+ 9.6 ton (S)+19.2 ton (T) +9.6 ton (S)+19.2 ton (T)	5 %	-

Note : S=Single Axle, T=Tandem Axle

Based on the above distribution, 18-kip ESAL of each axle is obtained from Appendix D of the AASHTO Guide and taking into account the shares of trucks by type, the average number of 18-kip ESALs per truck (Truck Load Factor) is calculated as shown in Table 5.

Table 5 Truck Load Factor

C-3 (p_t=2.5, SN=3)

Vehicle Type	Share	Axle Load - 1 Axle Load - 4				Axle Load - 2 Axle Load - 5				Axle Load - 3				Σ ALEF	Σ ALEF x Share
		*	ton	kips	ALEF	*	ton	kips	ALEF	*	ton	kips	ALEF		
Truck (5.0 ton or less)	30%	S	1.0	2.2	0.001	S	4.0	8.8	0.078			-		0.079	0.024
Truck (9.0 ton)	25%	S	1.8	4.0	0.004	S	7.2	15.9	0.634			-		0.638	0.160
Truck (18.0 ton)	20%	S	3.6	7.9	0.049	T	14.4	31.7	0.861			-		0.910	0.182
Semi-trailer (18.0 ton)	10%	S	3.6	7.9	0.049	T	14.4	31.7	0.861			-		0.910	0.091
Trailer (32.4 ton)	10%	S	3.6	7.9	0.049	S	9.6	21.1	1.864	T	19.2	42.3	2.565	4.478	0.448
Double-trailer (61.2 ton)	5%	S	3.6	7.9	0.049	S	9.6	21.1	1.864	T	19.2	42.3	2.565	8.907	0.445
		S	9.6	21.1	1.864	T	19.2	42.3	2.565						
													Truck Load Factor		1.350

C-2 (p_t=2.5, SN=4)

Vehicle Type	Share	Axle Load - 1 Axle Load - 4				Axle Load - 2 Axle Load - 5				Axle Load - 3				Σ ALEF	Σ ALEF x Share
		*	ton	kips	ALEF	*	ton	kips	ALEF	*	ton	kips	ALEF		
Truck (5.0 ton or less)	30%	S	1.0	2.2	0.000	S	4.0	8.8	0.065			-		0.065	0.020
Truck (9.0 ton)	25%	S	1.8	4.0	0.003	S	7.2	15.9	0.632			-		0.635	0.159
Truck (18.0 ton)	20%	S	3.6	7.9	0.040	T	14.4	31.7	0.858			-		0.898	0.180
Semi-trailer (18.0 ton)	10%	S	3.6	7.9	0.040	T	14.4	31.7	0.858			-		0.898	0.090
Trailer (32.4 ton)	10%	S	3.6	7.9	0.040	S	9.6	21.1	1.811	T	19.2	42.3	2.498	4.349	0.435
Double-trailer (61.2 ton)	5%	S	3.6	7.9	0.040	S	9.6	21.1	1.811	T	19.2	42.3	2.498	8.658	0.433
		S	9.6	21.1	1.811	T	19.2	42.3	2.498						
													Truck Load Factor		1.317

Lologo Radial Road (p_t=2.5, SN=3)

Vehicle Type	Share	Axle Load - 1				Axle Load - 2				Axle Load - 3				Σ ALEF	Σ ALEF x Share
		*	ton	kips	ALEF	*	ton	kips	ALEF	*	ton	kips	ALEF		
Truck (5.0 ton or less)	40%	S	1.0	2.2	0.001	S	4.0	8.8	0.078			-		0.079	0.032
Truck (9.0 ton)	30%	S	1.8	4.0	0.004	S	7.2	15.9	0.634			-		0.638	0.191
Truck (18.0 ton)	10%	S	3.6	7.9	0.049	T	14.4	31.7	0.861			-		0.910	0.091
Semi-trailer (18.0 ton)	10%	S	3.6	7.9	0.049	T	14.4	31.7	0.861			-		0.910	0.091
Trailer (32.4 ton)	10%	S	3.6	7.9	0.049	S	9.6	21.1	1.864	T	19.2	42.3	2.565	4.478	0.448
													Truck Load Factor		0.853

Nyakuron Radial Road (p_t=2.5, SN=4)

Vehicle Type	Share	Axle Load - 1				Axle Load - 2				Axle Load - 3				Σ ALEF	Σ ALEF x Share
		*	ton	kips	ALEF	*	ton	kips	ALEF	*	ton	kips	ALEF		
Truck (5.0 ton or less)	40%	S	1.0	2.2	0.000	S	4.0	8.8	0.065			-		0.065	0.026
Truck (9.0 ton)	30%	S	1.8	4.0	0.003	S	7.2	15.9	0.632			-		0.635	0.191
Truck (18.0 ton)	10%	S	3.6	7.9	0.040	T	14.4	31.7	0.858			-		0.898	0.090
Semi-trailer (18.0 ton)	10%	S	3.6	7.9	0.040	T	14.4	31.7	0.858			-		0.898	0.090
Trailer (32.4 ton)	10%	S	3.6	7.9	0.040	S	9.6	21.1	1.811	T	19.2	42.3	2.498	4.349	0.435
													Truck Load Factor		0.832

ALEF : Axle Load Equivalency Factor
* S : Single Axle T : Tandem Axle

The traffic load (w_{18}) is calculated as shown in Table 6.

Table 6 Traffic Load

	Cumulative Two-directional Number of Trucks	Truck Load Factor	$\hat{w}_{18}$	D_D	D_L	w_{18}
C-2	26,358,000	1.317	34,713,000	0.5	1.0	17,357,000
C-3	9,890,000	1.350	13,352,000	0.5	1.0	6,676,000
Lologo Radial Rd.	14,885,000	0.853	12,697,000	0.5	1.0	6,349,000
Nyakuron Radial Rd.	12,997,000	0.832	10,814,000	0.5	1.0	5,407,000

Reliability

Reliability is a means of incorporating some degree of certainty into the design process to ensure that the various design alternatives will last the analysis period. The reliability design factor accounts for chance variations in both traffic prediction (w_{18}) and the performance prediction (W_{18}), and therefore provides a predetermined level of assurance (R) that pavement sections will survive the period for which they were designed.

The AASHTO Guide suggests the level of reliability (R) for urban principal arterials, collectors and local to be 80–99%, 80–95% and 50–80% respectively. In this Study, R is set at 80%. The standard normal deviate (Z_R) and combined standard error of the traffic prediction and performance prediction (S_o) are set as follows:

Z_R = -0.841 (corresponding to R=80% from Table 7)

S_o =0.45 (suggested value by the AASHTO Guide based on the AASHO Road Test)

Table 7 Standard Normal Deviate (Z_R) Values Corresponding to Selected Levels of Reliability

Reliability, R (%)	Standard Normal Deviate, Z_R	Reliability, R (%)	Standard Normal Deviate, Z_R	Reliability, R (%)	Standard Normal Deviate, Z_R
50	0	90	-1.282	96	-1.751
60	-0.253	91	-1.340	97	-1.881
70	-0.524	92	-1.405	98	-2.054
75	-0.674	93	-1.476	99	-2.327
80	-0.841	94	-1.555	99.9	-3.090
85	-1.037	95	-1.645	99.99	-3.750

Source : The AASHTO Guide

Performance Criteria

Pavement performance is represented by the serviceability history of a pavement. The serviceability of a pavement is defined as its ability to serve the type of traffic (automobiles and trucks) which use the facility. The primary measure of serviceability is the Present Serviceability Index (PSI), which ranges from 0 (impossible road) to 5 (perfect road).

Selection of the lowest allowable PSI or *terminal serviceable index* (p_t) is based on the lowest index that will tolerated before rehabilitation, resurfacing, or reconstruction becomes necessary. An index of 2.5 or higher is suggested by the AASHTO Guide for design of major highways and 2.0 for highways with lesser traffic volumes.

The *initial serviceability index* (p_o) is the value immediately after construction. p_o observed at the AASHO Road Test was 4.2 for flexible pavement.

The total change in serviceability index is expressed by $\triangle PSI = p_o - p_t$

In this design, p_o and p_t are established at 4.2 and 2.5 respectively.

Roadbed soil

The resilient modulus (M_R) is used to characterize roadbed soil property. The AASHTO Guide introduces the equation estimating M_R from CBR or R-value, as follows:

M_R (psi)=1,500 x CBR

This equation, which is considered reasonable with a soaked CBR of 10 or less, is used in this Study limiting to CBR of 10 (regarding 10 in case of CBR more than 10).

According to the CBR test results, the CBRs of all design sections are 10 or more, except for Nyakuron Radial Road where the CBR is 7. Accordingly, the resilient moduli are estimated to be 15,000 psi for all design sections, except for Nyakuron Radial Road where the resilient modulus is 10,500 psi.

Pavement Structure

Structural Layer Coefficient

The pavement strength is expressed by the structural number (SN) which is indicative of the total pavement thickness required. In order to convert actual layer thickness into SN, the structural layer coefficients (a_i) are required. The AASHTO Guide provides the charts that may be used to estimate the structural layer coefficients.

Based on the charts, the following structural layer coefficients are assumed in this Study :

- Asphalt concrete surface course : a_1 = 0.390 (in case of E_{AC}^*=350,000 psi)
- Granular base course : a_2 = 0.135 (in case of CBR=80)
- Granular subbase course : a_3 = 0.094 (incase of CBR=20)

* E_{AC} : elastic modulus of asphalt concrete at 68°F

Drainage Coefficient

The structural layer coefficients are modified considering the effects of certain levels of drainage on predicted pavement performance. The factor for modifying the structural layer coefficient is referred to as m_i value. The recommended m_i values are given in the AASHTO Guide as shown in Table 8.

Table 8 Recommended m_i values for Modifying Structural Layer Coefficients of Untreated Base and Subbase Materials in Flexible Pavements

Quality of Drainage		Percent of Time Pavement Structure is Exposed to Moisture Levels Approaching Saturation			
		Less than 1 %	1 – 5 %	5 – 25 %	Greater than 25 %
Excellent	(water removed within 2 hours)	1.25 – 1.20	1.35 – 1.30	1.30 – 1.20	1.20
Good	(water removed within 1 day)	1.20 – 1.15	1.25 – 1.15	1.15 – 1.00	1.00
Fair	(water removed within 1 week)	1.15 – 1.10	1.15 – 1.05	1.00 – 0.80	0.80
Poor	(water removed within 1 month)	1.10 – 1.00	1.05 – 0.80	0.80 – 0.60	0.60
Very poor	(water will not drain)	1.00 – 0.90	0.95 – 0.75	0.75 – 0.40	0.40

Source : The AASHTO Guide

In this Study, m_2 and m_3 are estimated at 1.00 assuming that the quality of drainage is fair and that the pavement structure is exposed to moisture levels approaching saturation during 5 % of the year.

Summary

Table 9 summarizes the design inputs.

Table 9 Summary of Design Inputs

Item	Design Conditions/Assumptions	C-2	C-3	Lologo Radial Road	Nyakuron Radial Road
Performance Period	10 years	2016- 2025	2016- 2025	2021- 2030	2021- 2030
Traffic	Directional Distribution Factor (D_D) = 0.5 Truck Load Factor 1.317 (C-2), 1.350 (C-3), 0.853 (Lologo Radial Road), 0.832 (Nyakuron Radial Road)	W_{18} =17,357,000	W_{18} =6,676,000	W_{18} =6,349,000	W_{18} =5,407,000
Reliability	Level of Reliability (R) - Standard Normal Deviate (Z_R) - Combined Standard Error of the Traffic Prediction and Performance Prediction (S_o)	R=80 % Z_R=-0.841 S_o=0.45	R=80 % Z_R=-0.841 S_o=0.45	R=80 % Z_R=-0.841 S_o=0.45	R=80 % Z_R=-0.841 S_o=0.45
Performance Criteria	Initial Design Serviceability Index (p_o) Design Terminal Serviceability Index (p_t) - Deference between p_o and p_t (△PSI)	p_o=4.2 p_t=2.5 △PSI=1.7	p_o=4.2 p_t=2.5 △PSI=1.7	p_o=4.2 p_t=2.5 △PSI=1.7	p_o=4.2 p_t=2.5 △PSI=1.7
Roadbed Soil	Resilient Modulus (M_R) = 1,500 x CBR (CBR<10) = 15,000 (CBR≥10)	M_R=15,000 (CBR≥10)	M_R=15,000 (CBR≥10)	M_R=15,000 (CBR≥10)	M_R=10,500 (CBR=7)
Structural Layer Coefficient	Asphalt Concrete Surface Course (a_1) = 0.390 (E_{AC}=350,000 psi) Granular Base Course (a_2) = 0.135 (CBR=80) Granular Subbase Course (a_3) = 0.094 (CBR=20)	a_1=0.390 a_2=0.135 a_3=0.094	a_1=0.390 a_2=0.135 a_3=0.094	a_1=0.390 a_2=0.135 a_3=0.094	a_1=0.390 a_2=0.135 a_3=0.094
Drainage	Quality of drainage is fair (water removed within 1 week). Pavement structure is exposed to moisture levels approaching saturation during 5% of the year. - Drainage Coefficient of Granular Base Course (m_2) = 1.0 - Drainage Coefficient of Granular Subbase Course (m_3) = 1.0	m_2=1.0 m_3=1.0	m_2=1.0 m_3=1.0	m_2=1.0 m_3=1.0	m_2=1.0 m_3=1.0

(3) Design

Procedure

The pavement structural design is carried out in the following procedures:

① Determine the design inputs, including
- W_{18} (predicted number of 18-kip ESAL applications,
- Z_R (standard normal deviate),
- S_o (combined standard error of the traffic prediction and performance prediction),
- △PSI (difference between the initial design serviceability index, po, and the design terminal serviceability index, pt, and
- M_R (roadbed soil resilient modulus in psi).

② Determine the design structural number (SN) required applying the Basic Design Equation for Flexible Pavement (shown in (1) above).
The AASHTO Guide gives the nomograph for determining SN.

③ Select the materials and thicknesses of layers composing the pavement structure, including asphalt concrete surface course, base course and subbase course. Then, calculate the structural number and check it against the required SN determined in ② above.

Required Structural Number

Table 10 shows the required structural number.

Table 10 Required Structural Number

		C-2	C-3	Lologo Radial Road	Nyakuron Radial Road
Inputs	W_{18}	17,357,000	6,676,000	6,349,000	5,407,000
	Z_R	-0.841	-0.841	-0.841	-0.841
	S_o	0.45	0.45	0.45	0.45
	△PSI	1.7	1.7	1.7	1.7
	M_R	15,000	15,000	15,000	10,500
Required SN		**3.946**	**3.381**	**3.353**	**3.738**

Selection of Pavement Materials

The following materials are selected.

- Surface course : dense-graded asphalt concrete with elastic modulus (E_{AC}) of 350,000 psi at 68° F
- Base Course : mechanically stabilized crushed stone with CBR=80
- Subbase Course : crusher-run with CBR=20

Structural Number (SN)

The structural number (SN) is calculated by the following equation :

$SN = a_1D_1 + a_2D_2m_2 + a_3D_3m_3$

Table 11 shows the SNs of various thicknesses of pavement.

Table 11 Structural Numbers of Various Thicknesses of Pavement

AC Surface Course (a_1=0.390)

Thickness (cm) t_1	a_1	D_1		$a_1 \cdot D_1$
5	0.390	1.969		0.768
10	0.390	3.937		1.535

Base Cource (a_2=0.135, m_2=1.0)

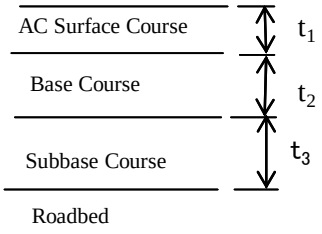
Thickness (cm) t_2	a_2	D_2	m_2	$a_2 \cdot D_2 \cdot m_2$
10	0.135	3.937	1.0	0.531
15	0.135	5.906	1.0	0.797
20	0.135	7.874	1.0	1.063
25	0.135	9.843	1.0	1.329

Subbase Cource (a_3=0.094, m3=1.0)

Thickness (cm) t_3	a_3	D_3	m_3	$a_3 \cdot D_3 \cdot m_3$
15	0.094	5.906	1.0	0.555
20	0.094	7.874	1.0	0.740
25	0.094	9.843	1.0	0.925
30	0.094	11.811	1.0	1.110
35	0.094	13.780	1.0	1.295

Combination

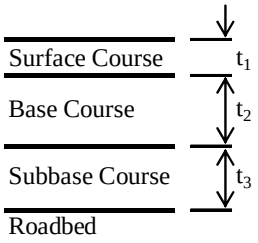
Thickness (cm) t_1-t_2-t_3	SN
5-10-15	0.768 + 0.531 + 0.555 = 1.854
5-10-20	0.768 + 0.531 + 0.740 = 2.039
5-15-25	0.768 + 0.797 + 0.925 = 2.490
5-15-30	0.768 + 0.797 + 1.110 = 2.675
5-20-35	0.768 + 1.063 + 1.295 = 3.126
10-10-15	1.535 + 0.531 + 0.555 = 2.621
10-10-20	1.535 + 0.531 + 0.740 = 2.806
10-15-25	1.535 + 0.797 + 0.925 = 3.257
10-15-30	1.535 + 0.797 + 1.110 = 3.442
10-20-30	1.535 + 1.063 + 1.110 = 3.708
10-20-35	1.535 + 1.063 + 1.295 = 3.893
10-25-35	1.535 + 1.329 + 1.295 = 4.159



Selection of Layer Thicknesses
Table 12 shows the thicknesses selected.

Table 12 Layer Thicknesses Selected

		C-2	C-3	Lologo Radial Road	Naykuron Radial Road
Thickness	Surface Course (t_1)	10 cm	10 cm	10 cm	10 cm
	Base Course (t_2)	25 cm	15 cm	15 cm	20 cm
	Subbase Course (t_3)	35 cm	30 cm	30 cm	35 cm
	Total	70 cm	55 cm	55 cm	65 cm
Structural Number (SN)		4.159	3.442	3.442	3 893
Required Structural Number		3.946	3.381	3.353	3.738



The structural number (SN) is superior to the required.

APPENDIX 14 DESIGN OF GRAVEL ROADS FOR 2nd PILOT PROJECT

A14.1 Design Standard and Reference

- The design of gravel road structure for the 2nd Pilot Project shall be based on the "Pavement Design Manual", Ministry of Transport and Roads, Government of Southern Sudan, (USAid) 2006.

A14.2 Design Principle

- The essential consideration is "to ensure all-weather access"
- Surface performance shall be given due attention such a minimal dust generation in populated areas, proper gravel materials on steep gradients, provision for gravel loss, etc., and
- Provision of gravel surface that is effectively maintainable.

A14.3 Design Methodology

The required gravel structure thickness shall be decided as follows:

1) Determine the minimum thickness to avoid excessive compressive strain in the subgrade (D_1).
2) Determine the extra thickness needed to compensate for the gravel loss under traffic during the period between regravelling operations (D_2).
3) Determine the total gravel thickness by adding the above two thicknesses (D_1+D2).

A14.4 Design for Gravel Wearing Course

A14.4. 1 Minimum Pavement Structure Thickness (D_1)

The thickness (D_1), as shown in Figure A14.4-1, is decided based on the minimum gravel thickness required for each category with the required thickness of improved subgrade materials for upper and lower subgrade layers.

The choice of pavement structure is based on:

- the Annual Average Daily Traffic ($AADT_{design}$) for the road under consideration, and
- the existing subgrade/road bed CBR (CBR_{design})

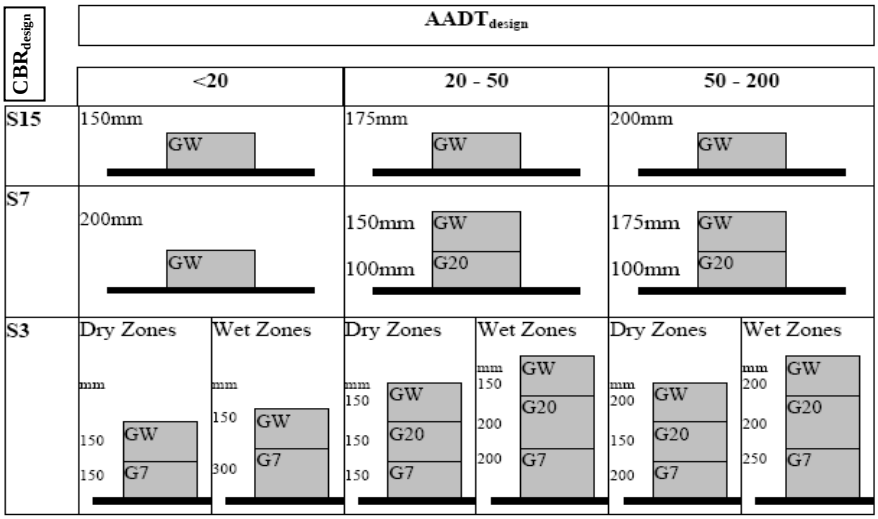


Figure A14.4-1 Pavement and Improved Subgrade for Gravel Roads for AADTs <200

(Source: Pavement Design Manual, Ministry of Transport and Roads, Government of Southern Sudan, (USAid) 2006)

There are three sections considered for the 2nd Pilot Project road, as follows:

Table A14.4-1 Pavement Structure from Catalog (Figure A14.4-1)

Station			$AADT_{design}$	Subgrade CBR_{design}	Pavement Structure (mm)*		
From	To	Length (m)			D_1	G20	G7
0+000	0+240	240	50-100	32	200	-	-
0+240	0+335	95	50-100	5-6	200	150	200
0+335	0+500	165	50-100	32	200	-	-

Notes: 1. GW – Gravel Wearing Course

2. For G20 and G7 definitions, see Table A14.4-2

A14.4.2 Gravel Loss (D_2)

The annual gravel loss is given by:

$$GL = fT^2/(T^2+50)\ (4.2+0.092T+3.5R^2+1.88V)$$

where :

GL = annual gravel loss in mm

T = total traffic volume in the first year measured in both directions, in thousands of vehicles (use 40,000 pcu)

R = average annual rainfall, in m (use 1m)

V = total (rise + fall) as percentage of the length of road (use 5%)

f = 0.94 to 1.29 for lateritic gravels (use 1.0)
1.1 to 1.51 for quartizitic gravels
0.7 to 0.96 for volcanic gravels (weathered lava or tuff)
1.5 for coral gravels
1.38 for sandstone gravels

Table A14.4-2 Soils for Subgrade Layers

Table 11-1: Soils for Subgrade Layers		
Material Properties	**G20 (Upper Layer)**	**G7 (Lower Layer)**
CBR Dry Climatic Zones (See Note)	Minimum 20 after 4 days soaking	Minimum 7 after 4 days soaking
CBR Wet Climatic Zones (See Note)	Minimum 20 at OMC Minimum 7 after 4 days soaking	Minimum 7 at OMC Minimum 3 after 4 days soaking
PI [%]	Maximum 25	Maximum 30
Compacted Density	95% of AASHTO T180	95% of AASHTO T180
Maximum particle size	2/3 of layer thickness	2/3 of layer thickness
Compacted layer thickness	Maximum 200 mm	Maximum 250 mm

(Source: Pavement Design Manual, Ministry of Transport and Roads, Government of Southern Sudan, (USAid) 2006)

Therefore, anticipated annual loss is:

$GL = [\mathbf{1.0} \times \mathbf{40}^2/(\mathbf{40}^2+50)]\ (4.2+0.092\times\mathbf{40}+3.5\times\mathbf{1.0}^2+1.88\times\mathbf{5})$
$= 0.97 \times 20.78$
$= 20.16$ mm

Use **GL = 25mm**

Taking D_2 = NxGL (where N is the period between regraveling operations in years),

$D_2 = 1 \times 25$ (**N = 1** year; regraveling should be done once or twice a year)
D_2 = 25mm

A14.4.3 Total Thickness of Gravel Wearing Course (GW)

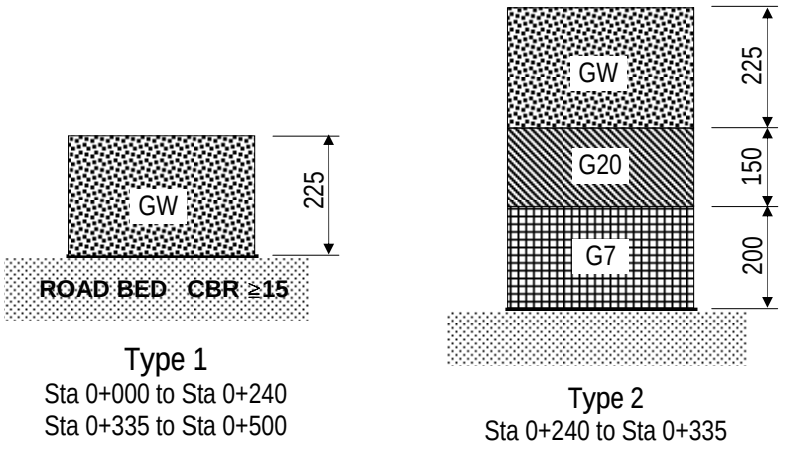
The wearing course for the gravel road becomes:

$$GW = D_1 + D_2$$

Table A14.4-3 Design Pavement Structure for Road Sections

Station			Proposed Pavement Structure Type (mm)*				
From	To	Length (m)	GW			G20	G7
			D_1	D_2	Total		
0+000	0+240	240	200	25	225	-	-
0+240	0+335	95	200	25	225	150	200
0+335	0+500	165	200	25	225	-	-

The pavement structures at different road sections are illustrated in Figure A14.4-2.



Note: For purposes of capacity development, the gravel wearing course thickness used for the 2nd Pilot Project is taken at 150mm which is the present standard for gravel roads being implemented by MTR.

Figure 4.2 Proposed Pavement Structure Types

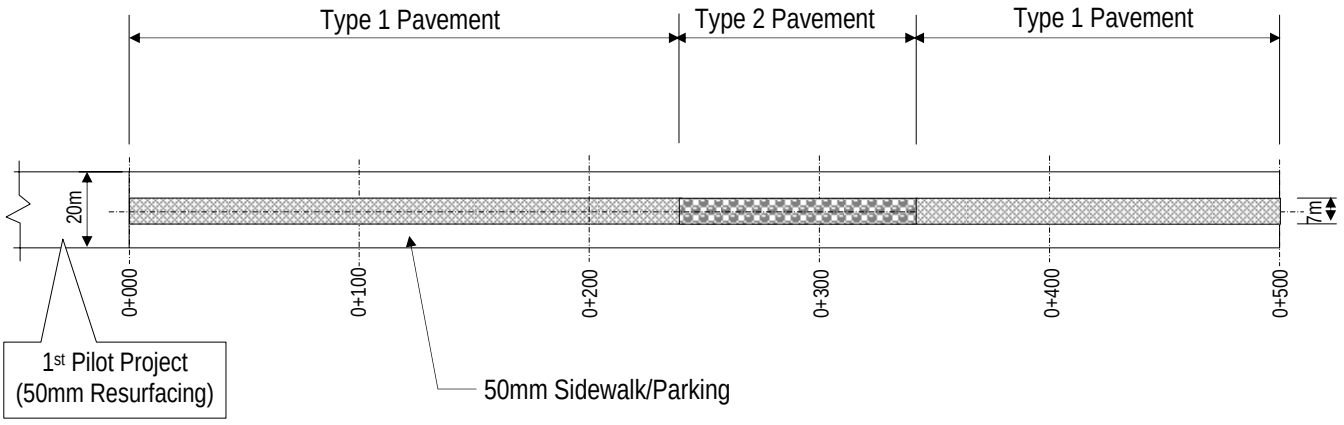


Figure A14.4-3 Layout of Pilot Project Road

A14.5 Specifications for Gravel Wearing Course Materials

The "Pavement Design Manual – 2006" specifies that materials for gravel wearing course shall consist of hard durable angular particles of fragments of stone or gravel and shall be free from vegetable matter and lumps or balls of clay. The grading of the gravel materials shall be as recommended in Table A14.5-1.

Table A14.5-1 Gravel Wearing Course Gradations

Test Sieve Size(mm)	Percent(%) by mass of total aggregate passing test sieve					
	Type 1	Type 2	Type 3	Type 4	Type 5	Type 6
50	-	-	-	100	-	-
37.5	100	-	100	80-100	-	-
28	-	100	95 - 100	-	-	-
20	80 - 100	95 - 100	85-100	60-80	100	-
14	-	80-100	65 - 100	-	-	-
10	55 - 100	65 - 100	55 - 100	45-65	80 - 100	100
5	40 - 60	45 - 85	35-90	30-50	60 -85	80-100
2.36	30 - 50	-	-	20-40	45-70	50-80
2	-	30 - 65	22-75	-	-	-
1	-	25-55	18-60	-	-	-
0.425	15 - 30	18 - 45	15-50	10-25	25-45	25-45
0.075	5 - 15	12-32	10-40	5-15	10-25	10-25