CHAPTER 9
DEVELOPMENT OF ROAD MAINTENANCE MANUAL FOR CAPACITY BUILDING OF ROAD MAINTENANCE

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9.1 General

Road infrastructure is one of the necessary fundamental factors for improving the socio-economic performance of a nation. Because of this, it cannot be stressed enough that proper maintenance after the completion of road construction is therefore essential. To consistently ensure road maintenance of a sufficient quality, it is important that the engineers, inspectors, technicians, etc. involved in road maintenance use the same methodologies and tools. The purpose of the road maintenance manual, which is contained in separate text, is to ensure such consistency by providing standard methodologies and tools based on the experiences and characteristics of Kenya. This Chapter, in addition to discussing guidelines for road design and axle-load control, also discusses the makeup and characteristics of the maintenance manual.

9.2 Road Maintenance Manual

9.2.1 Introduction

There are several road maintenance manuals in Kenya. However, these manuals have not been effectively used by road maintenance engineers and contractors. Moreover, some road engineers have developed simple road maintenance manuals themselves and are using these. Therefore, road maintenance is not standardized in Kenya.

The proposed road maintenance manual, which was developed for KRB by the JICA Study Team in cooperation with Kenyan government organizations, takes into account the situation in Kenya as well as existing road maintenance manuals. It is hoped that consistency in the field of road maintenance will be achieved in Kenya via KRB's application of said road maintenance manual to all of its roads, which covers the entire public road network. The policies for the development of the road maintenance manuals are as follows:

(a) To develop manuals suitable for the Kenyan environment
(b) To develop user-friendly manuals
- for inspection, evaluation, and execution of maintenance
- for routine, periodic, and urgent maintenance

(c) To distribute sufficient numbers of manuals for workers in the field
(d) To include maintenance specifications from the manuals in contracts

Given this background, the proposed road maintenance manual shall be comprised of the following three volumes:

Part I : Inspection Manual
Part II : Evaluation Manual
Part III : Execution Manual

Figure 9.2.1 shows the composition of each of the volumes comprising the road maintenance manual.

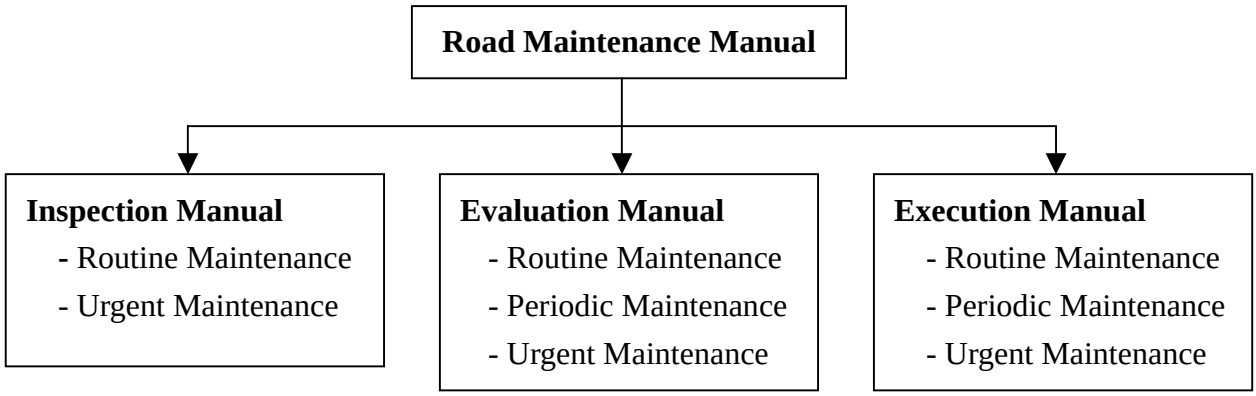

Figure 9.2.1 Composition of Road Maintenance Manual

Although the manual has carefully considered the basic conditions of Kenya, engineers and inspectors should take into account the basic characteristics of their respective regions when actually applying the manual. Engineers and inspectors may also wish to refer to the following handbooks and manuals for additional information:

(a) International Road Maintenance Handbook, Volume I, II, III, IV, PIARC, 1994
(b) Road Maintenance Handbook, Volume I, II, III, IV, UN, 1982
(c) Road Maintenance Manual, RD of MORPW, 1992
(d) Road 2000 Works Manual, SDC, 1996

9.2.2 Composition of Manual

The three volumes of the road maintenance manual address both paved and unpaved roads. Paved roads are defined as cement concrete roads, asphalt concrete roads and surface dressed roads. Unpaved roads are defined as gravel and earth roads. The manual also covers routine, periodic, and urgent maintenance. The definitions of these activities are as follows:

(1) Inspection Manual

The Inspection Manual describes the inspection methods for inspectors and contains the following:

- Glossary of terms
- Contents of manuals
- Inspection items including defect descriptions
- Inspection sheets and methods
- Frequency of inspection activities
- Safety methods for inspection

Table 9.2.1 shows an example of a “Definition of Defect” sheet contained in the Inspection Manual. This sheet includes the description of a defect, its possible causes, effects, reporting methods, inspection tools, and a photograph of the defect.

Table 9.2.1 Definition of Defects

DEFINITION OF DEFECT	KENYA ROADS BOARD	
Item: Paved Roads (Bitumen)	**Sub-Item: Surface**	**Defect: Rutting/Deformation**

Description:

Rutting is characterised by longitudinal depressions in the pavement surface that occur in the wheel paths of a roadway.

Possible Causes:

- Inadequate pavement thickness.
- Inadequate compaction in surfacing or base.
- Inadequate strength (stability) in surfacing or base.
- Excessive bitumen in the mix.
- Excessive axle loads.

Effect (if neglected):

- If water is able to penetrate into the body of the pavement, then there will be a rapid increase in the degree of rutting often leading to cracking and break-up of the pavement.
- If excessive can reduction in serviceability and reduce vehicle travel speeds and in very severe cases, may be an accident risk.

Inspection Reporting Method:

- Scaling average depth.

Inspection Tools:

- Tape

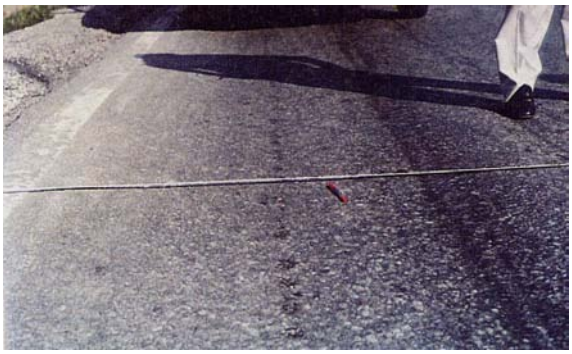

Table 9.2.2 **Form 1 Road Condition Survey for Paved Roads (Routine)** ____ of ____

District			Date of Inspection		/ /		Inspector's Name					
Road No.					/ /		Pavement Type		Concrete or Asphalt Concrete or Surface Dressing			
Location	km from		Road Class		Class							
Location (km)			0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0
Shoulder (Left Side)	Defects	Obstructions										
		High Vegetation										
		Scour										
		Shoulder/Carriageway Step										
		Rutting/Depressions										
		Potholes (Area x Depth x Nos.)										
	Cause of Defects											
Carriageway	Defects	Cracking										
		Potholes (Area x Depth x Nos.)										
		Rutting/Deformation (Depth)										
		Heaving/Shoving										
		Stripping/Fretting										
		Bleeding										
		Glazing										
		Edge Damage										
		Wave										
		Obstruction										
		Spot Failure of Base Course										
		Loss of Surface Texture										
		Joint Settlement										
	Cause of Defects											
Footpath	Defects	Pothole/Depressions										
		Obstructions										
Shoulder (Right Side)	Defects	Obstructions										
		High Vegetation										
		Scour										
		Shoulder/Carriageway Step										
		Rutting/Depressions										
		Potholes (Area x Depth x Nos.)										
	Cause of Defects											
Terrain:Mountainous(M), Rolling(R), Hilly(H) or Flat (F)												

The following five (5) routine inspection sheets have been prepared:

- Form PR : Paved Roads
- Form UR : Unpaved Roads
- Form RF/RS : Road Furniture and Roadside Structures
- Form DSS : Drainage System and Drainage Structures
- Form URB : Road Facilities in Urban Roads

An example of an inspection sheet is shown in Table 9.2.2. The basis of each inspection sheet is as follows:

- All defects items to be inspected are shown on a sheet.
- Each sheet covers a 2 km section of road.
- The following basic data is entered on each inspection sheet:
  District name, Date of inspection, Inspector's name, Road number, Road class, Surface type, Location, Terrain and Cause of defect.

Table 9.2.3 shows the condition ranking of defects. This ranking consists of four ranking levels from "A" to "D". Also, the road elements for ranking are divided into four items below.

- Carriageway and shoulder
- Drain (Ditches)
- Culverts
- Others

Figure 9.2.2 shows the "Basic Flow for Inspection Activities".

Table 9.2.3 Condition Ranking of Defects

Ranking	Rank A	Rank B	Rank C	Rank D
Carriageway and Shoulder	(1) Minor defects (2) Vehicles can pass at normal design speed for paved roads or at a speed of more than 60 km/hr for unpaved roads. (3) No immediate action but need to continue monitoring. (4) Removing obstructions	(1) Minor defects (2) Vehicles can pass at normal design speed for paved roads or at a speed of 60 to 40 km/hr for unpaved roads. (3) Normal routine maintenance required such as: - Local sealing, Crack sealing, Spot sealing - Grading - Patching - Manual reshaping - Sanding (4) Removing obstruction	(1) Major defects (2) Vehicles can pass at a speed of 40 to 20 km/hr, but running conditions are not smooth. (3) Routine or periodic maintenance required such as: - Heavy grading (recovery of material + compaction) - Manual heavy reshaping - Regavelling - Resealing (4) Removing obstructions	(1) Major defects (2) Vehicles cannot pass at a speed of more than 20 km/hr. (3) Routine or periodic maintenance required such as: - Heavy reshaping - Regravelling - Overlay, Surface dressing (5) Reconstruction including rehabilitation (6) Emergency maintenance required (7) Removing obstructions
Drain (Ditches)	(1) Minor defects (2) No immediate action but need to continue monitoring. (3) Removing obstructions	(1) Minor defects such as: - Local erosion - 1/2 silted drainage (2) Collapse but functions maintained (3) Normal routine maintenance required such as: - Cleaning - Local reconstruction (4) Removing obstructions	(1) Major defects such as: - 3/4 silted drainage - Ditch lining is damaged - Ponding (2) Collapse but functions maintained (3) Routine or periodic maintenance required such as: - Cleaning - Repair lining - Reshape (4) Removing obstructions	(1) Major defects such as: - Erosion - Fully silted drainage (2) Collapse and functions lost (3) Routine or periodic maintenance required such as: - Cleaning (4) Reconstruction including rehabilitation (5) Emergency maintenance required (6) Removing obstructions

(Cont'd)

Ranking	Rank A	Rank B	Rank C	Rank D
Culvert	(1) Minor defects - Spot cracking (2) No immediate action but need to continue monitoring. (3) Removing obstructions	(1) Minor defects such as: - Cracking - Local collapse - 1/2 silted culvert (2) Collapse but functions maintained (3) Normal routine maintenance required such as: - Sealing - Cleaning - Repair for local collapse (4) Removing obstructions	(1) Major defects such as: - Collapse - 3/4 silted culvert (2) Collapse but functions maintained (3) Routine or periodic maintenance required such as: - Cleaning - Local reconstruction (4) Removing obstructions	(1) Major defects such as: - Collapse - Fully silted culvert (2) Collapse and functions lost (3) Routine or periodic maintenance required such as: - Cleaning (4) Reconstruction including rehabilitation (5) Emergency maintenance required (6) Removing obstructions
Others	(1) Minor defects - Spot crack (2) No immediate action but need to continue monitoring. (3) Removing obstructions	(1) Minor defects such as: - Local erosion - Dirty of road furniture - Crack (2) Collapse but functions maintained (3) Normal routine maintenance required such as: - Filling - Cleaning - Crack sealing (4) Removing obstructions	(1) Major defects such as: - Collapse - Damaged road furniture (2) Collapse but functions maintained (3) Routine or periodic maintenance required such as: - Local reconstruction - Repair of road furniture (4) Removing obstructions	(1) Major defects such as: - Collapse - Settlement - Earth slip/landslide - Missing road furniture (2) Collapse and functions lost (3) Routine or periodic maintenance required such as: - Replacement of road furniture (4) Reconstruction including rehabilitation (5) Emergency maintenance required (6) Removing obstructions

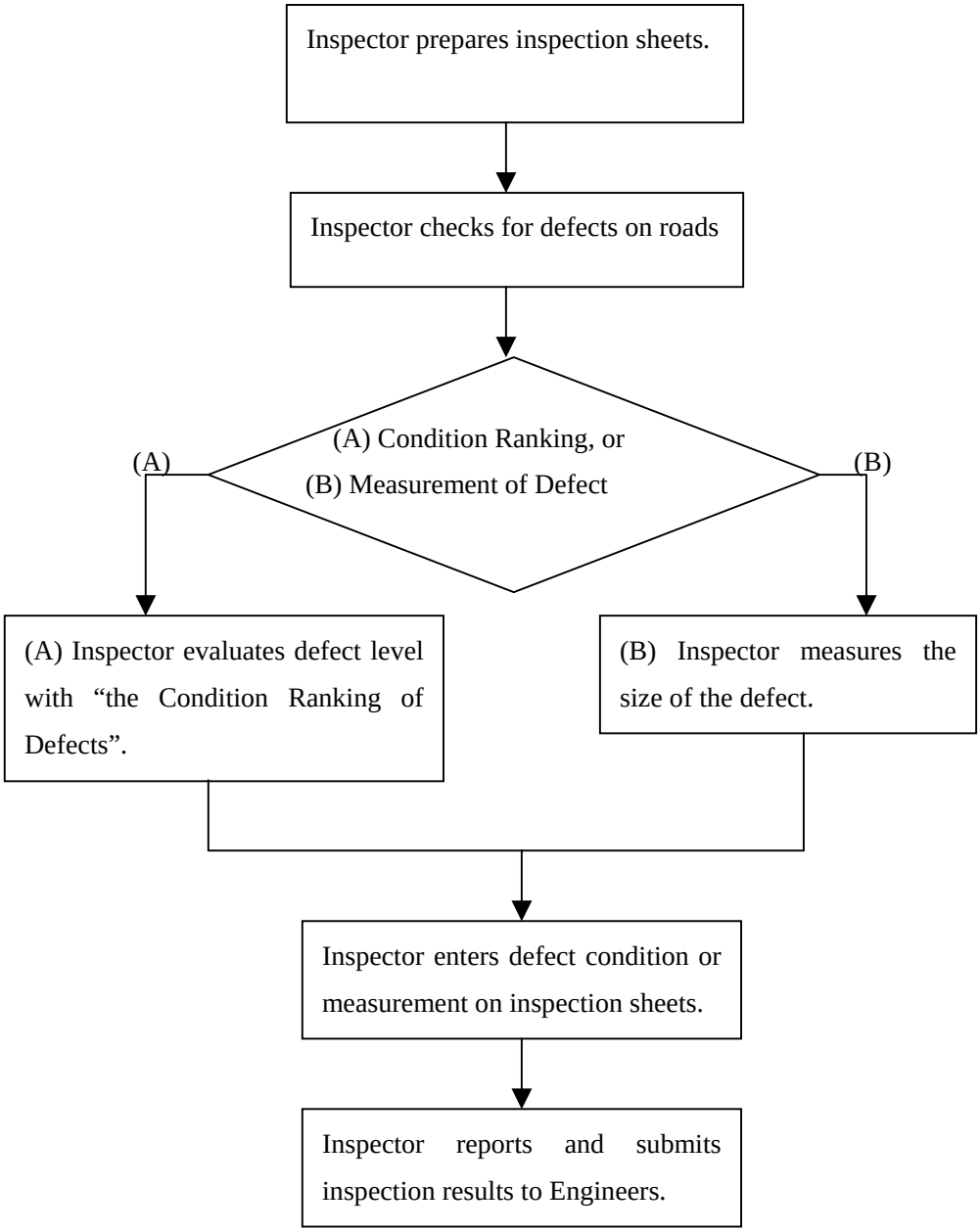

Figure 9.2.2 Basic Flow for Inspection Activities

(2) Evaluation Manual

The Evaluation Manual describes the evaluation methods for defects and the selection methods for execution works. This manual is prepared for engineers and contains the following:

- Glossary of terms
- Contents of manuals
- Execution works

- Selection of execution works
- Reporting of execution plan

Figure 9.2.3 shows the "Basic Flow for Evaluation Activities".

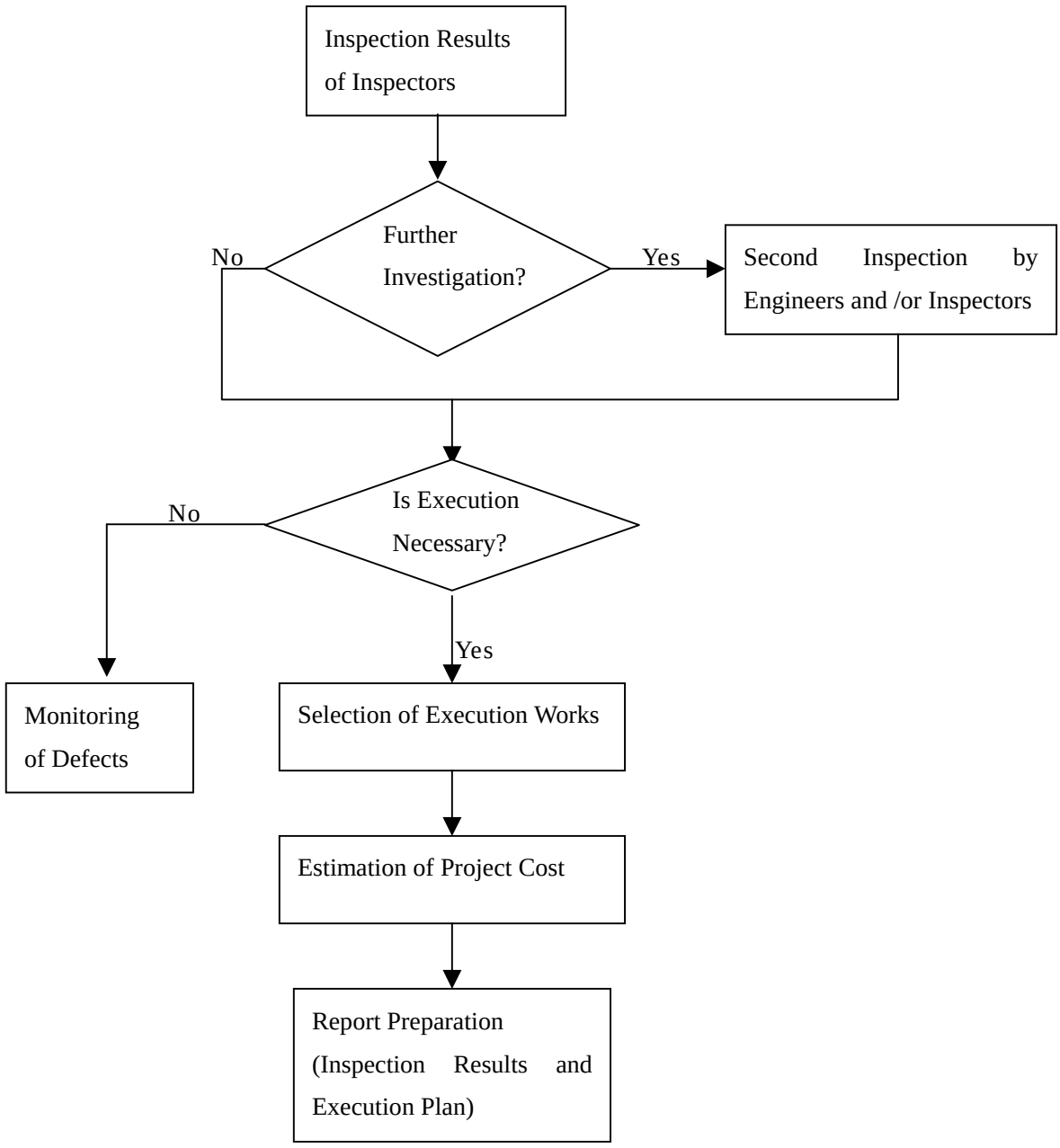

Figure 9.2.3 Basic Flow for Evaluation Activities

(3) Execution Manual

The Execution Manual describes the methods for repair works, cleaning and clearing based on the evaluation results of the engineers. This manual includes the following:

- Glossary of terms
- Contents of manuals
- Contents of each execution method include activity specification
- Safety method during execution of the works

There are three types of road maintenance and they are described below.

(a) Routine Maintenance

Maintenance requiring execution once or more times per year on a section of road and that is typically small in scale or simple, but widely dispersed and requiring skilled or un-skilled manpower. The need for some routine maintenance can be estimated and planned on a regular basis (e.g., vegetation control).

(b) Periodic Maintenance

Maintenance required occasionally on a section of road after a number of years and that is normally large in scale and usually requiring the temporary deployment of special equipment and skilled resources for implementation. Periodic maintenance is costly and requires specific identification and planning for implementation and often requires design work as well.

(c) Urgent Maintenance

Certain unforeseen situations necessitating remedial maintenance to be taken as soon as possible (e.g., flood damage, slips).

9.2.3 Items of Execution Works

Main defect items and details of maintenance work are as shown in Table 9.2.4.

Table 9.2.4 Execution Works by Defect

Item	Sub-Item	Defects	Routine Maintenance	Periodic Maintenance	Urgent Maintenance
Paved Roads (Bitumen)	Surface	Cracking	Spot sealing	Resealing	
			Crack sealing	Surface dressing	
			Patching	Overlay	
		Potholes	Patching	Surface dressing	
				Overlay	
		Rutting/Deformation	Patching	Planing	
			Spot planing	Overlay	
		Heaving/Shoving	Patching	Planing	
			Spot planing	Overlay	
		Stripping/Fretting	Spot sealing	Resealing	
				Surface dressing	
				Overlay	
		Bleeding	Sanding	Overlay	
		Glazing	Sanding	Surface dressing	
		Edge damage	Patching	Spot Reconstruction	
			Spot reconstruction		
		Waving	Patching	Overlay	
		Obstructions	Moving obstructions		Moving obstructions
	Base course	Spot failure	Base repair		
	Sub-base	Spot failure	Sub-base repair		
	Subgrade	Spot failure	Subgrade repair		
Concrete Roads		Loss of Surface Texture		Re groove surface	
		Cracking	Sealing		
		Joint Settlement		Pressure/vacuum grouting	
				Bitumen overlay	

(Cont'd)

Item	Sub-Item	Defects	Routine Maintenance	Periodic Maintenance	Urgent Maintenance
Unpaved Roads	Carriageway	Loss of camber	Reshaping	Grading	
			Grading	Regravelling	
		Rutting	Reshaping	Grading	
			Grading	Regravelling	
			Dragging		
		Potholes	Filling	Grading	
			Patching	Regravelling	
		Corrugations	Reshaping	Grading	
			Grading	Regravelling	
			Dragging		
		Erosion gullies	Reshaping	Grading	
			Grading	Regravelling	
			Dragging		
		Soft spots	Filling	Grading	
			Spot patching (Replace with better material)	Regravelling	
			Grading		
			Dragging		
		Obstructions	Moving obstructions		Moving obstructions
		Loss of Gravel Depth		Regravelling	
Shoulder		Obstructions	Moving obstructions		Moving obstructions
		High vegetation	Bush clearing		
		Scour	Filling	Reconstruct	
			Spot reconstruction	Add ditch	
		Shoulder/carriageway step	Spot reconstruction	Reshaping	
				Grading	
				Filling	
		Rutting	Filling	Grading	
		Depressions	Filling	Grading	
		Potholes	Filling		
			Patching		

(Cont'd)

Item	Sub-Item	Defects	Routine Maintenance	Periodic Maintenance	Urgent Maintenance
Slopes		High vegetation	Bush clearing		
		Erosion	Filling	Install cut-off ditch	Re-cut
			Re-cut	Grassing	
				Planting	
				Re-cut (Install berm)	
		Earth slip/landslide	Filling	Re-cut	Gabion installation
			Benching	Gabion installation	
			Grassing	Cribwork	
			Drainage	Retaining walls	
		Rock Avalanche	Remove unstable rock	Netting installation	Moving unstable rock
			Netting installation	Shotcrete	
			Shotcrete	Re-cut	
			Re-cut	Benching	
		Collapse of Slope Protection	Gabion installation	Reconstruction	
Embankments		Collapse		Filling/Gabion	Place warning signs
					Moving obstructions
		Settlement		Filling	Place warning signs
					Move obstructions
Drainage	**Culverts**	Silting	Clearing and cleaning		
		Blockage by debris	Clearing	Install debris rack	
		Settlement cracks	Sealing of cracks	Reconstruct culvert at correct level and fall	
		Erosion of stream bed at culvert outlet	Filling	Construct outfall basin	
		Headwall/apron/wingwall damage	Headwall/apron repair	Reconstruct (headwall/apron/wingwall)	
		Collapse of Culvert		Reconstruct culvert	

(Cont'd)

Item	Sub-Item	Defects	Routine Maintenance	Periodic Maintenance	Urgent Maintenance
Drainage	**Ditches and Drains**	Obstructions	Clearing		Moving obstructions
		Silting	Cleaning	Reshape, regrade or deepen	
				New mitre drain	
		Ponding in ditch or on shoulder		Reshape, regrade or deepen	
				New mitre drain	
		Invert and sides of ditch are eroded	Regrade/realign	Regrade/realign	
			Line ditch	Line ditch	
			Provide scour protection	Provide scour protection	
		Ditch lining is damaged	Repair lining	Realign ditch	
		Erosion at drainage outfall		Construct cascade	
				Flatten gradient (Regrade)	
				Construct new mitre drain	
				Reconstruct ditch	
	Manholes and Drainage Pipes	Water is flowing up at manhole	Clear manhole and pipes	Relay pipes	Place warning signs
		Manhole cover or grating is missing	Replace cover or grating		Replace cover or grating
		Manhole is covered with soil and vegetation	Clear manhole area		
		Catchpit sump is silted up	Clean catchpit sump		
Structures	**Drifts and Causeways**	Settlement		Repair works	
		Erosion	Clearing		
		Debris	Clearing		Clearing
		Guide posts are damaged or missing	Replace or repair guide posts		
	Retaining Walls/Stone Masonry	Settlement		Reconstruction	
		Cracking	Sealing	Reconstruction	
		Collapse	Gabion installation	Reconstruction	
				Gabion installation	
Road Furniture		Dirty	Cleaning		
		Damaged	Repair/replace	Repair/replace	
		Missing	Replace	Replace	
Footpath		Pothole/depression	Filling		
			Patching		
		Obstructions			Moving obstruction

9.2.4 Training of Kenyan Engineers in Use of Maintenance Manual

It is recommended that the Kisii Training Center (KTC) design and carry out training, which will include on-site practice, using the JICA road maintenance manual as a standard. In ANNEX 11, a draft of KTC's program for such training is attached for reference. In order to achieve the previously mentioned standardization, it is recommended that all road agencies have their engineers and technicians trained by KTC in the use of the manual, which was developed in a cooperative effort between JICA and the Kenya Roads Board, the Kenyan Ministry of Roads and Public Works, the Kenyan Ministry of Local Government, Kenya Wildlife Service, and the Nairobi City Council. Moreover. It is also suggested that trainees provide feedback to Kisii one year after finishing to ensure that they are performing as intended.

Finally, the road maintenance manual should be updated periodically to reflect changes in the field of road maintenance or to make necessary modifications, revisions, or corrections. It is recommended that the Kenya Roads Board be responsible for keeping digital copies of the three volumes of the manual at its office in Nairobi so **official** versions of the manual can be distributed as required. The process depicting the distribution, training in the use of, and revision of the JICA road maintenance manual is as shown in Figure 9.2.4 below.

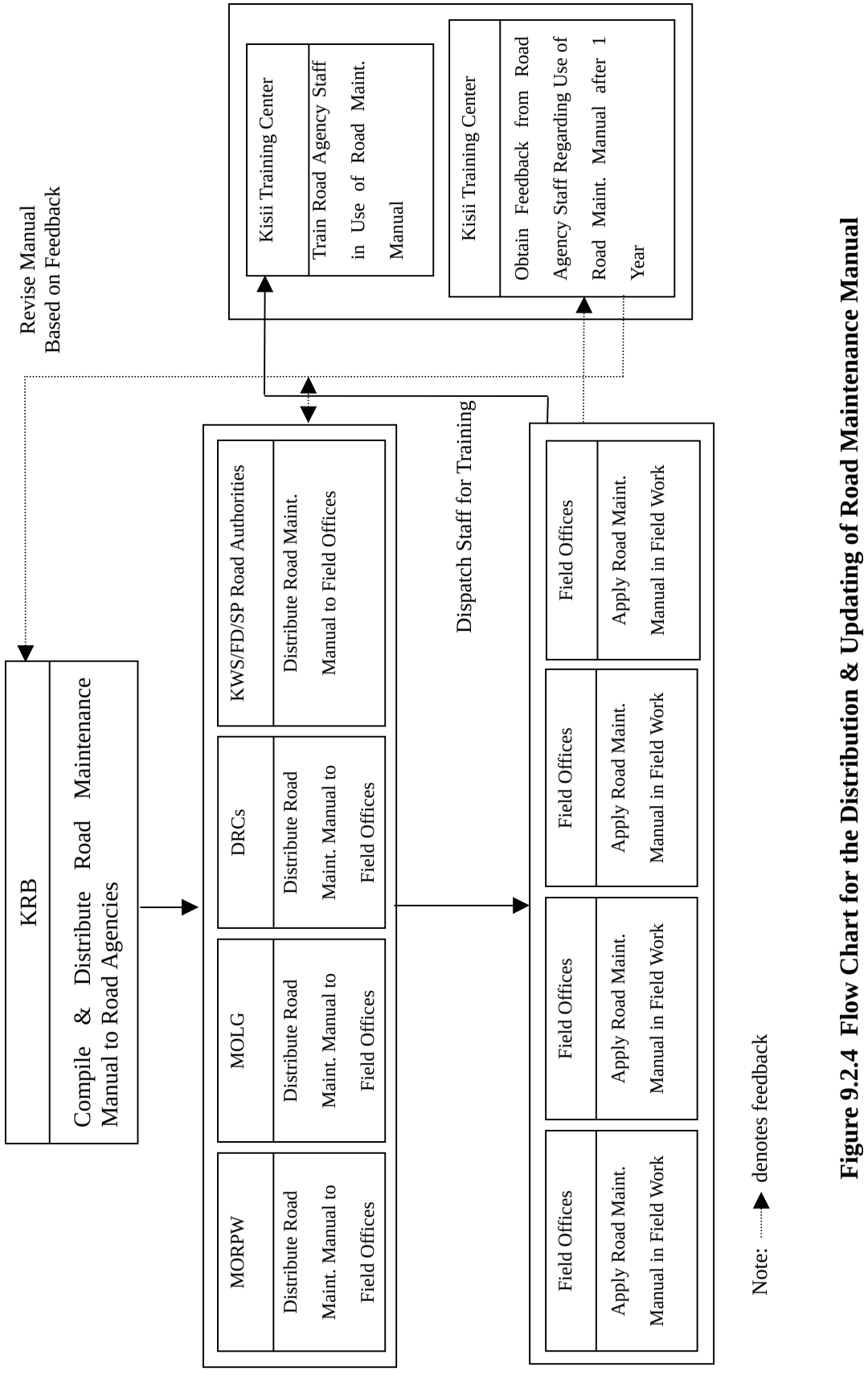

Figure 9.2.4 Flow Chart for the Distribution & Updating of Road Maintenance Manual

9.3 Guidelines for Road Design

9.3.1 Introduction

The purpose of road maintenance is to always ensure good road conditions at an acceptable level of clearing, inspection, defect evaluation, and maintenance work. In the road design stage, it is important to ensure that good road conditions be achieved at an acceptable level of cost. That is, appropriate road design will be linked to the minimizing of road maintenance costs.

In Kenya, road design manuals have been developed and are in use. The guidelines for road design examine important matters for the reduction and prevention of road defects. Axle-load calculations for pavement design are also an important factor for preventing pavement defects.

In this section of Chapter 4, guidelines for road design is examined to ensure that costs to achieve required levels of service for roads are appropriate.

9.3.2 Guidelines for Road Design

If roads are properly designed, they can be kept in good condition for a long period of time. Also, the number of defects that the roads experience will be reduced. The main points for proper road design are examined below in items (1) to (5).

(1) Pavement Design

There are many types of pavement defects such as cracking, potholes, rutting, and bleeding. They are caused by the following:

- Underestimation of traffic volumes.
- Underestimation of axle loads.
- Overloaded vehicles
- Insufficient strength of designed materials for the surface, base and sub-base course, and subgrade.
- Improper construction, such as a lack of compaction, and insufficient quality control over materials, asphalt concrete temperatures, etc.

Pavement structures are designed based on the design period, traffic volume by vehicle type, axle loads, strength of materials, and strength of the subgrade (CBR).

In Kenya, there are 14 typical pavement structures for paved roads using surface dressing and asphaltic-concrete, which are defined by the type of base and sub-base course (see "Road Design Manual (Part III)"). Each type is divided into a standard pavement structure based on the strength of the subgrade (CBR) and traffic conditions (i.e., equivalent standard axle (ESA)) as shown in Table 9.3.1.

Table 9.3.1 Subgrade and Traffic for Pavement Design

Subgrade		Traffic	
Class	CBR (%)	Class	ESA x 10^6
S 1	2 - 5	T 1	25 - 60
S 2	5 - 10	T 2	10 - 25
S 3	7 - 13	T 3	3 - 10
S 4	10 - 18	T 4	1 - 3
S 5	15 - 30	T 5	0.25 - 1
S 6	> 30	T 6	-

Note : ESA means "Equivalent Standard Axle".

As for gravel roads, required gravel thickness is calculated as follows:

- Determine minimum thickness necessary to avoid excessive compressive strain in the subgrade (D_1).
- Determine the extra thickness needed to compensate for gravel loss due to traffic loads during the period between re-gravelling operations (D_2).

Figure 9.3.1 shows the typical pavement structure for both gravel roads and paved roads.

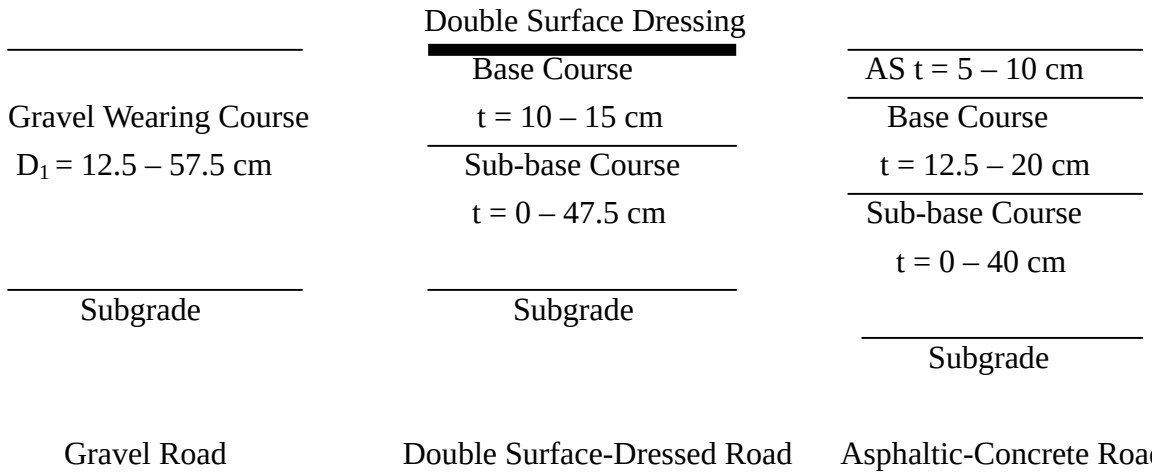

Figure 9.3.1 Typical Pavement Structure for Gravel & Paved Roads

In applying standard pavement structures, designers should consider the following points:

- Traffic volume by vehicle type and axle-load are important factors for pavement design. If future traffic volumes and axle loads are underestimated, the road's surface will be damaged in a short time. To ensure these factors are accurately estimated, future regional development plans, the socio-economic framework, present traffic volumes, etc., should be taken into account. In the Road Design Manual, a constant growth rate for traffic volume is stated to be 7.5% for a design period of 15 years. However, this rate should be reviewed due to changes in economic and traffic conditions.
- The strength of materials for the surface course, base course, sub-base course, and subgrade are also important issues for proper pavement design. Thus, the strength of materials should be tested before actually being used.
- The standard maximum thickness of an asphaltic-concrete surface is 10 cm. This maximum thickness seems to be too thin for sections with a high percentage of heavy vehicles. Therefore, the maximum thickness is recommended to be15 cm.
- The design period for pavement design is decided based on road class and economy (including road maintenance costs). Basically, the design period is 15 to 20 years.

(2) Shoulder Design

Common problems affecting shoulders are washing out, depressions, potholes, and rutting. These problems are caused by water and/or traffic flows. At present, the basic shoulder types used are as follows:

- Shoulder with extended base and sub-base course
- Cement or lime-treated shoulder
- Gravel shoulder
- Earth shoulder

Generally, the types of shoulders suitable for heavy traffic are (a), (b), or (c). Also, if there is much heavy traffic, the following shoulder protection methods should be considered:

- Topsoiling and grassing
- Priming and sanding
- Surface dressing

The type of shoulder and protection method should be selected based on cost-effectiveness, traffic volume, and rainfall.

Also, side ditches on the edge of a shoulder should be taken into consideration to prevent the washing out of shoulders and the erosion of slopes. Figure 9.3.2 shows a typical plan for a side ditch.

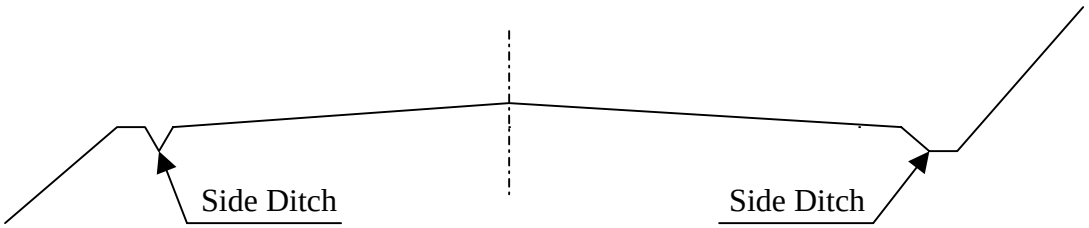

Figure 9.3.2 Typical Plan for a Side Ditch

(3) Embankment Design (including Slope Design)

The major maintenance issues for embankments are collapse and settlement, while for slopes they are erosion, landslides, rock avalanches, and the collapse of protection. Embankments should be designed taking into consideration the strength of fill materials, side ditches on the edges of shoulders, and natural ground conditions such as soft soil (e.g., Black Cotton Clay) or rock.

Slopes should be designed taking into consideration the relationship between the gradient and fill materials or natural ground. The basic slope gradient for cut and embankment sections are described below.

Slope Gradient of Cut Section

- Cohesion-less sand 1 : 2
- Silty sand (silts) 1 : 1
- Alluvial soils (red friable clays)
  1.5 : 1 $h \leq 4$ m
  1 : 1 $h > 4$ m
- Weathered rock 2 : 1 to 4 : 1
- Sound rock 5 : 1 to 10 : 1

Slope Gradient of Embankment Section

- Cohesion-less sand	1 : 3	h ≤ 1 m
	1 : 2	h > 1 m
- Other materials	1 : 3	h ≤ 1 m
	1 : 2	1 m < h ≤ 3 m
	1 : 1.5	h > 3m

Note : "h" means cut or embankment height.

Slope protection from erosion should consider the following measures:

- Topsoiling and grassing
- Surface treatment with seed and fertilizer
- Gravel or stone blanketing
- Concrete crib

The installation of crossing drainage, pipe culverts, and box culverts should be based on discharge capacity and suitable intervals to prevent the collapse and erosion of embankments and slopes.

(4) Ditch

Problems with ditches include their collapse, erosion, and silting. If large problems occur, the pavement, embankment or slope could also be affected. The velocity of ditch flows should be controlled to prevent collapse and erosion. Therefore, the vertical gradient of ditches is important. Basic maximum permissible velocities by material type are shown in Table 9.3.2.

Table 9.3.2 Maximum Permissible Velocity

Materials	Max. Permissible Velocity (m/s)
Fine sand	0.3
Silt – Coarse sand	0.4 – 0.6
Silty clay – Fine gravel	0.5 – 0.8
Stiff clay	0.9 – 1.3
Coarse gravel	1.2 – 1.7
Soft rock – Conglomerate	1.8 – 2.5
Hard rock – Masonry – Concrete	3.0

Velocity should also be controlled to prevent the accumulation of sediment. Basic minimum permissible velocities by material type are shown in Table 9.3.3.

Table 9.3.3 Minimum Permissible Velocity

Materials	Min. Permissible Velocity (m/s)
Silt	0.08
Fine sand	0.15
Coarse sand	0.20
Fine gravel	0.30
Gravel	0.65

In addition, in order to protect ditches, the following measures should be considered.

- Grassing
- Turfi
- Stone pitching
- Placing of stone masonry
- Concreting
- Placing of constructing steps

(5) Pipe and Box Culverts

Problems with pipe and box culverts include their collapse, defects in wing-walls, and settlement. These problems can affect embankments and slopes. To prevent this, culvert design should take the following into consideration:

- To prevent the collapse of culverts, the relationship between the strength of culverts and earth-cover thickness should be considered. Minimum earth-cover thickness is 0.20 m; however, it is recommended that minimum earth-cover thickness be increased to 0.60 m.
- If the strength of a culvert or earth-cover is insufficient, then a culvert foundation should be considered as shown below:

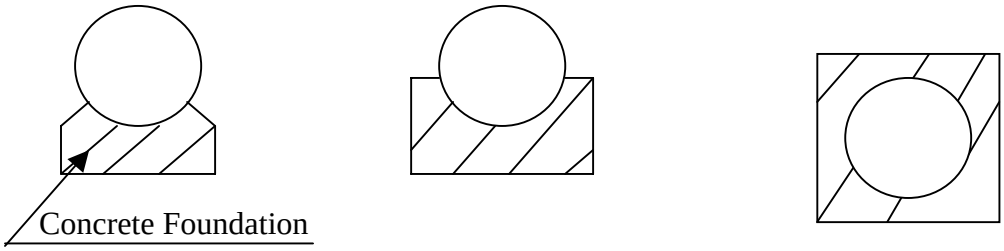

Figure 9.3.3 Concrete Foundation of Culverts

- To prevent settlement, the culvert foundation and natural ground conditions should be taken into consideration. Especially, if the culvert is installed on soft soil, a pile foundation or the replacement of the soft soil should be studied.

9.4 Axle-load Regulations

9.4.1 Present Axle –load

The deterioration of paved roads caused by traffic flows is a result of both the magnitude of individual wheel loads and the number of times these loads occur. The objective of controlling axle loads is to maximize the life of roads and thereby minimize the costs of maintenance. Normally, when axle-load limits are exceeded, the total cost and damage to roads increases rapidly, which can have an adverse effect on the economy overall. Therefore, axle-load controls are a crucial factor for not only preventing road surface damage but for protecting the roads or arteries that carry the economic life's blood of the country.

Axle loads in Kenya were studied during the period 1975 to 1980, which resulted in the following values being established as legal limits:

Maximum Gross Vehicle Weight
Vehicle with 2 axles : 160 kN (16,000 kg)
Vehicle with 3 axles : 220 kN (Rigid) (22,000 kg) , 260 kN (Semi-trailer) (26.000 kg)
Vehicle with 4 axles : 340 kN (34,000 kg)
Vehicle with 5 axles : 400 kN (40,000 kg)
Vehicle with 6 axles : 460 kN (46,000 kg)

At present, maximum total vehicle weight is 540 kN (54,000 kg), which is a vehicle with 7 axles.

Maximum Axle Loads
Front steering axle (2 wheel) : 80 kN (8,000 kg)
Single axle (4 wheels) : 100 kN (10,000 kg)
Tandem axle : 160 kN (16,000 kg)
Triple axle : 240 kN (24,000 kg)

Figure 9.4.1 shows typical axle-load limits.

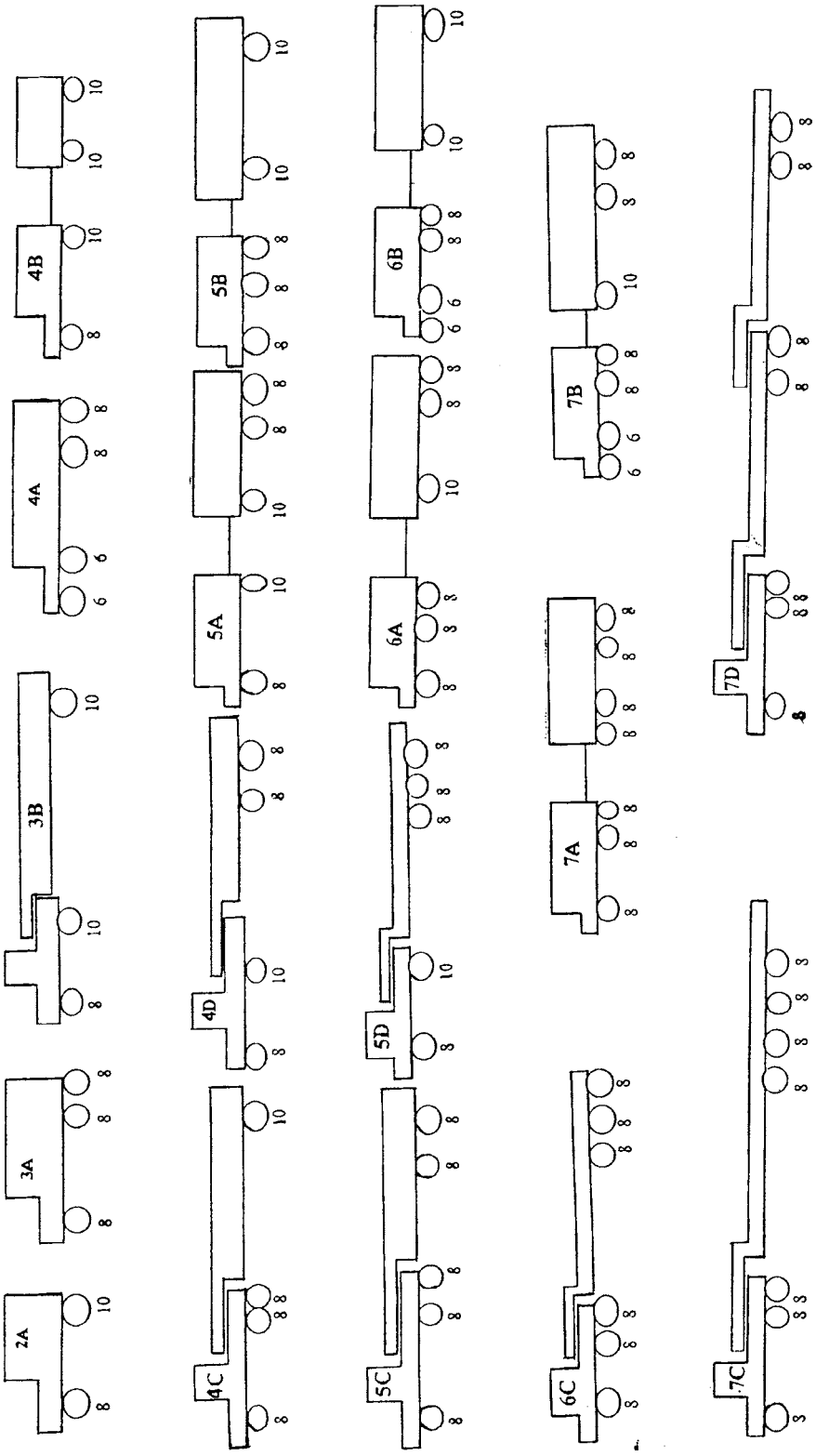

Figure 9.4.1 Typical Axle-load Limits

9.4.2 Existing Controls for Overloaded Vehicles

The existing method of controlling overloaded vehicles relies on the use of static weighbridges located at Mariakani, Athi River, Gilgil Webuye and Isebania. Government employees man these weighbridges on a 24-hour basis. Vehicles arriving at these sites are required to pass over the weighbridge so that the load on each axle can be checked to ensure it does not exceed the maximum allowed by law.

9.4.3 Investigation Results for Overloaded Vehicles

Many heavy commercial vehicles using Kenyan roads have been found with axle loads often much higher than that legally allowed. According to the "Investigation of Failures of Flexible Pavements" by Jomo Kenyatta University in March 2000, on Nairobi – Thika road, of the 4018 commercial vehicles weighed from 1998 to 1999, 551 commercial vehicles were overloaded by 50 – 3,000 kg in excess of the current axle-load limits. These vehicles accounted for 14 % of all vehicles weighed.

As for action in regards to overloaded vehicles, the road authority has been giving warnings to attending drivers. In addition, the Kenyan Government passed a traffic regulation to fine overloaded vehicles as of July 1999. As a result of this regulation, the average daily total weight of overloaded vehicles have been greatly reduced (see Figure 6.5.1). This data, which covers the time period between March 1998 and July 2001, indicates a value for March 1998 approx. 30 times greater than that for July 2001.

9.4.4 Proposal for Dealing with Overloaded Vehicles

As indicated in 9.4.3, there has been substantial success in dealing with the problem of overloaded vehicles. To further enhance this positive trend, the following is recommended:

- Continue with the strict enforcement of the axle-load regulation and the finding of tenders.
- Privatise weighbridges (as suggested by the EU) to promote better performance and thereby stricter adherence of axle load regulations by drivers.

CHAPTER 10
RECOMMENDATIONS

CHAPTER 10 RECOMMENDATIONS

As indicated in the previous chapters 6 to 9, the Study has proposed a comprehensive and holistic program to realize an efficient and effective road maintenance system, based on an analysis of funding for road maintenance and plausible future road maintenance scenarios in Kenya. The key recommendations to achieve the goal of making the system fully operational, which is in accordance with the framework of the Kenya Roads Board, are as follows:

(1) **Road inventory data, road condition data, and traffic data need to be updated urgently and continuously** to enable sensible decisions regarding maintenance, as well as to provide a basis for the justification of the allocation of funds.

(2) **Maintenance information/data should be retained on a user-friendly computer database** to enable engineers to monitor and analyze maintenance activities and costs for each type of road surface. There should also be a system for checking and updating data as well. Finally, the maintenance manual developed by the JICA Study Team should be kept in digital format and updated as indicated previously. KRB will be responsible for distributing and updating the manual and will hold its copyright.

(3) **The design and quality of construction of original pavement needs to be strictly controlled** to ensure maximum pavement life in order to get value for money from investment in road infrastructure.

(4) **Legal and institutional setup for road maintenance that includes finance, management and technical** issues need to be resolved based on the issues identified by the “Interim Steering Group” as soon as possible. In conjunction with this, the reform and reinforcement of road-related organizations in order to implement the KRB system as intended is to be carried out.

(5) **A national system of guidance for the preparation of Work Plans** is required, including a review of unit rates for maintenance works.

(6) **Standard contract documents need to be put in place for LBES works (simplified form of contract) and perhaps for equipment-based works** to encourage small-scale contractor participation in road maintenance. It is also important that there is a system to review and update this documentation.

(7) **Mechanical and Transport Department (MTD)** has the potential to provide equipment services for both the public and private sector if rationalization and commercialization are urgently carried out.

(8) **Kisii Training Center (KTC)** has the capacity to develop new training products (courses), and the training plan can be managed, executed and monitored by KTC (see ANNEX 11), but financial support shall be required. It is suggested that KTC also

develop new sources of revenue to supplement its cash flow.

(9) **Promotion of private sector capacity building** is crucial and small/medium-scale contracting needs to be assisted in two major areas: **access to resources** (i.e., credit, work, equipment, materials) and **establishment of an enabling environment for contracting** (i.e., prompt payment, simplified contracts, establishment of a contractor's association and contractor registration, and evaluation procedures).

(10) **It is suggested that JICA or some other international donor carry out a Pilot Study over a period of 1 to 2 years** with the purpose of monitoring and assisting with the implementation of the recommendations made in this Study. The Pilot Study would select a few districts for this work, which would then serve as a model for KRB and the rest of Kenya. Execution of the Pilot Study would be carried out with the support of Kisii Training Center, which would be in charge of training and would receive funding from KRB and/or the Donor as part of this work.

(11) To execute item (10), which will ultimately determine the effectiveness of all funding for road maintenance (including international funding), **it is suggested that a long-term expert from either JICA or another international agency be dispatched to KRB**. Note that the expert to be effective will have to possess a combination of skills that includes engineering, organizational development, and negotiating capabilities.

Having considered the various issues and recommendations stated previously, it is suggested that said issues and recommendations be resolved and implemented over a three-year period (2002 – 2005) in order to prevent the further deterioration of road conditions via the implementation of maintenance as required under the framework of the Kenya Roads Boards. The suggested implementation program for the three-year transition period to achieve this is as shown in the bar chart in Figure 10.1.

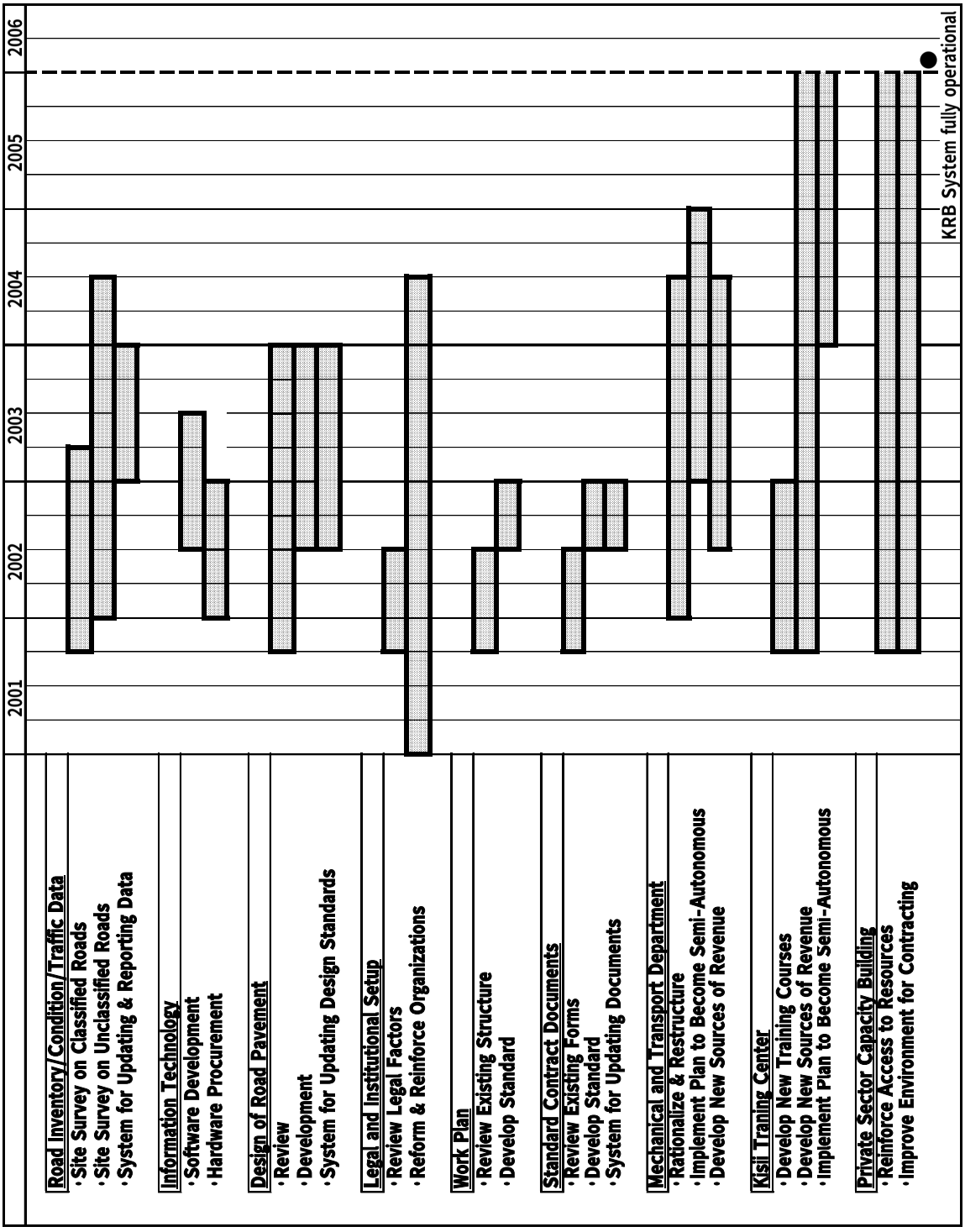

Figure 10.1 Implementation Program for Transition Period