MINISTRY OF PUBLIC WORKS AND TRANSPORT

General Directorate of Techniques
Road Infrastructure Department

Guidelines for Routine Road Maintenance Using IRI

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Main Text: Guidelines for Routine Road Maintenance Using IRI

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CHAPTER 1 Road Maintenance Cycle Using IRI

1.1 Outline of Road Maintenance System in Cambodia

1.1.1 Maintenance Category

In Cambodia, road maintenance system consists of the following 3 types of maintenance categories. "Guidelines for Routine Road Maintenance Using IRI" (hereafter called "the guidelines") aims at the 3 maintenance categories under Chapter 61.

(1) Routine Maintenance

Regular (daily) inspection for conditions of roads to examine items listed below;

- Pavement: potholes, cracks, ruts/settlements, deformations, local aggregate loss, edge break, scratches, bleeding etc.
- Cut and fill slopes
- Drainage
- Bridges: bottom, expansion joint etc.
- Other structures and facilities: markings, guardrails/handrails, signboards etc.

(2) Periodic Maintenance

Substantial repair works carried out at an appropriate time interval (every 3-year, 5-year, 8-year, 10-year etc.), based on the age, investment, and initial design of roads. It could also be required when vehicle weight and traffic volume increased. It includes reconstruction, improvement, or rehabilitation works on any road sections.

(3) Emergency Maintenance

Comprise works to restore roads and road-related facilities to their normal operating conditions after they are damaged by road accidents or natural causes. It is impossible to foresee the frequency, but such maintenance requires immediate action.

1.1.2 Roles and Responsibilities of Organizations Concerned with Road Maintenance

Roles and responsibilities of parties concerned with force accounting projects are summarized in Table-1. Basically, project formations are made up of Party A (employer), Party B (executor), Party C (supervisor), and Party D (inspector). Director General of Public Works (PW) is always in charge of "Party A". In case of routine road maintenance, which accounts for a large part of road maintenance (Chapter 61), "Party B", "Party C", and "Party D" are assigned to Department of Public Works and Transport (DPWT), Road Infrastructure Department (RID), Procurement Evaluation Award Committee (PEAC)/General Department of Inspection (GDI), respectively, as shown in Figure-1. In brief, DPWT plays main rolls under supervision of RID for planning and implementation of routine road maintenance.

Table-1 Roles and Responsibilities of Parties Concerned with Force Accounting Projects

		Executor (Party B)	Checking party/Supervisor (Party C)	Inspector (Party D)
New Construction/Reconstruction (Chapter 21)		HEC MRC DPWT/RCAF	PWRC RID SPIED	
Maintenance (Chapter 61)	Routine	DPWT	RID	PEAC/GDI
	Periodic	DPWT/MRC/ HEC/RCAF	RID/PWRC/SPIED	
	Emergency	MRC	RID	
Roles	Design stage	- Preparation of Basic Design - Preparation of Preliminary Cost Estimate for Construction - Preparation of Detailed Design - Preparation of Cost Estimate for Construction	- Checking Basic Design - Preparation of Preliminary Cost Estimate for Supervision - Check and Sum of Preliminary Project Cost - Checking Detailed Design - Preparation of Cost Estimate for Supervision - Check and Sum of Project Cost	
	Execution stage	Execution	Supervising	Inspection

Note : Party A: the employer, Director General of Public Works (PW)

HEC: Heavy Equipment Center

RID: Road Infrastructure Department

DPWT: Provincial Department of Public Works and Transport

RCAF: Royal Cambodian Army Force

PWRC: Public Works Research Center

PEAC: Procurement Evaluation Award Committee

GDI: General Department of Inspection

MRC: Prepare and Maintenance Roads Center

SPIED: Sub-National Public Infrastructure and Engineering Department

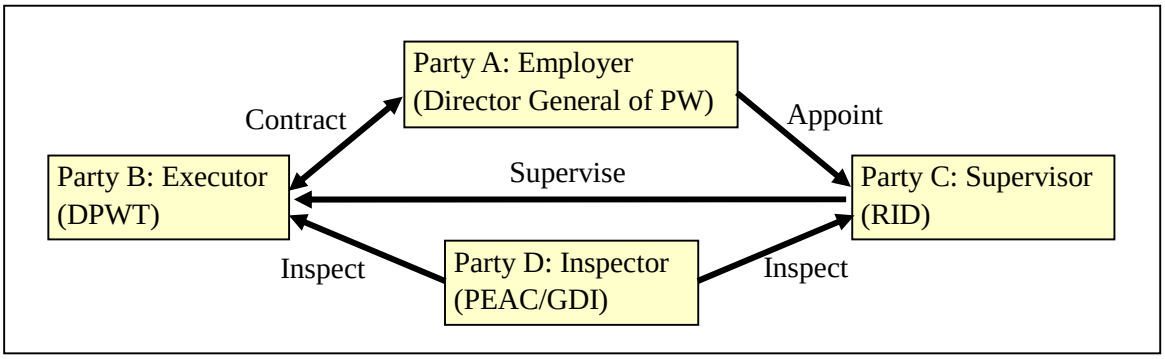


Figure-1 Formation of Parties for Routine Road Maintenance Projects (Force Accounting Projects)

1.2 Introduction of IRI into Road Maintenance System

A new road maintenance system was introduced into Cambodia through the technical assistant project, "The Project for Strengthening Capacity for Maintenance of Roads and Bridges (2015-2018)" (here after called the Project). The main feature of the new system is introduction of International Roughness Index (IRI). As shown in Figure-2, road surface conditions can be evaluated quantitatively by IRI. The evaluation system is effective for asset management and budget planning of road maintenance.

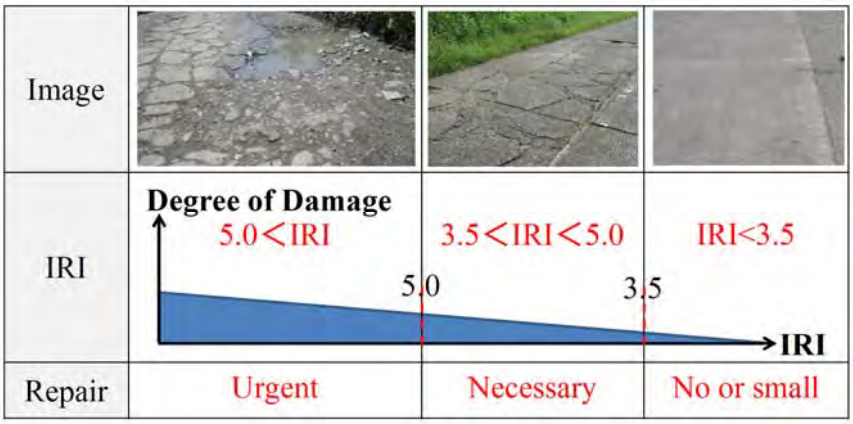


Figure-2 An example of Road Roughness Evaluation by IRI

As one of equipment for road roughness inspection (IRI-measurement), "vibration-based IRI measurement device" (DRIMS; see Appendix) was introduced in the Project. As illustrated in Figure-3, IRI values can be obtained by the measurement device through the following 3 steps;

- Step.1: Accurately measure "road profile/road roughness"
- Step.2: Process it through an algorithm that simulates vehicles' response to the road roughness (expressed as acceleration/vibration data)
- Step.3: Convert the vibration data into IRI values.

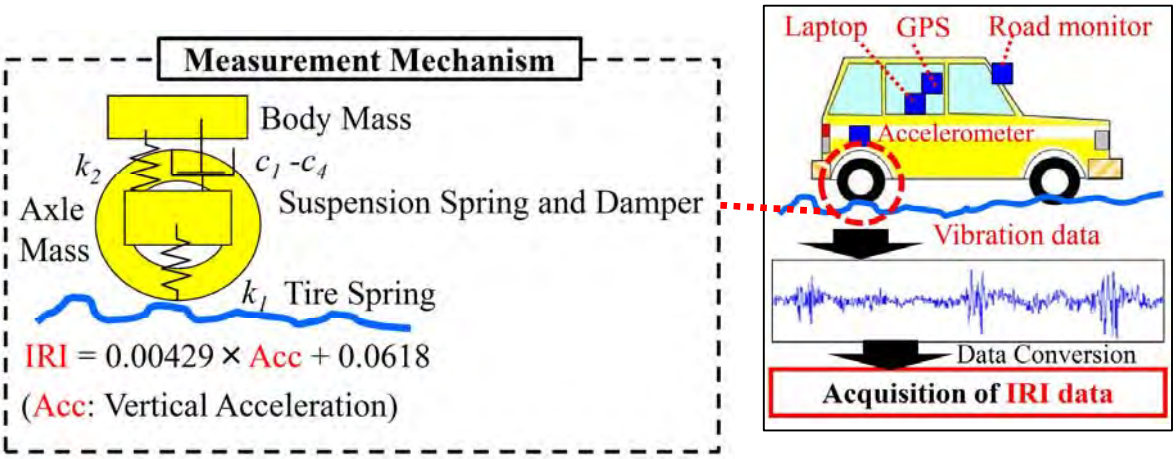


Figure-3 Mechanism of Vibration-based IRI Measurement

1.3 Road Maintenance Cycle Using IRI

1.3.1 Road Maintenance Cycle Using IRI

A new road maintenance cycle was established in Cambodia, integrating evaluation system with IRI into the existing road maintenance system, as shown in Figure-4. The maintenance cycle consists of 6 steps. Road inspections and evaluations are carried out in Step.1 through Step.3. After that, actual maintenance planning with cost estimate and implementation of the maintenance plans are carried out in Step.4 through Step.6.

Step.1 through Step.3 is an inspection stage. In Step.1, IRI measurement is conducted together with visual inspection. In Step.2, the inspection results are evaluated in combination of IRI values with visual inspection results. After that, road conditions are to be rechecked with the evaluation results at the sites by DPWT in order to decide target road sections for implementation of maintenance plans. In Step.3, road lists are prepared with the inspection evaluation results. Also, the maintenance necessity for the inspected roads is prioritized here, complying with 3 prioritization criteria; namely, 1) road classification, 2) road importance, and 3) road conditions.

After the inspection stage, the maintenance cycle step proceeds to planning and implementation stage. In Step.4, planning of maintenance methods and approximate cost estimation are carried out, based on the inspection evaluation results. The road sections selected for “reconstruction/rehabilitation/upgrade (Chap.21) are excluded from the target for routine road maintenance (Chap.61) and taken over by departments in authority. In Step.5, budget proposal for routine road maintenance is submitted to Ministry Economic and Finance (MEF). Finally, road maintenance plans are implemented in Step.6 after approval of the budget proposal by MEF. The maintenance cycle step goes back to Step.1 for feedback, and IRI measurement is carried out again. IRI values of the repaired road are compared with original values prior to the repair works in order to examine the effectiveness of the repair works.

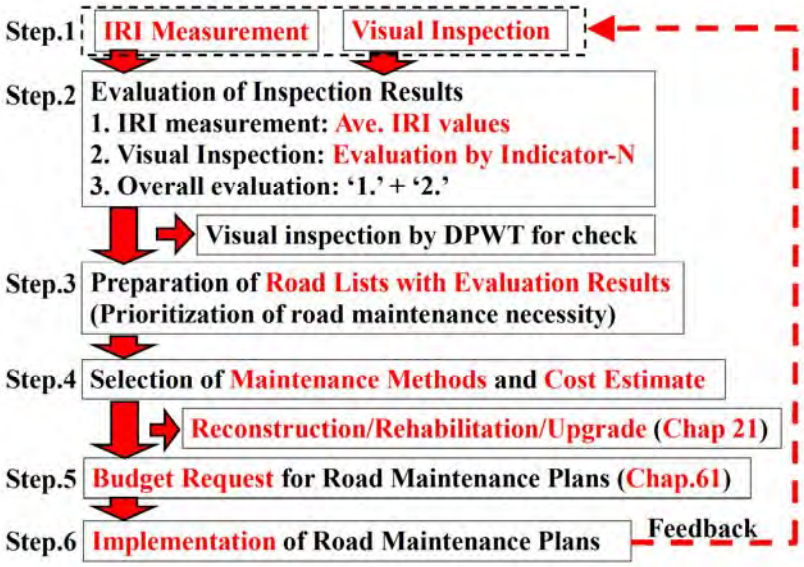


Figure-4 Road Maintenance Cycle Using IRI

1.3.2 Maintenance Procedure for Paved Roads

Table-2 describes maintenance procedure for paved roads. In Step.1 through Step.2, RID carries out IRI measurement and visual inspection simultaneously, and prepare DRIMS-based road Inventory called "Inventory". Inventory is to be summarized as "Inspection Review Sheet" with which RID gives instructions to DPWT for more detailed visual inspection. Then, DPWT updates Inspection Review Sheet with their inspection results. In Step.3, road lists are prepared based on Inspection Review Sheet, and maintenance necessity of the inspected roads are prioritized. In Step.4, RID and DPWT collaborate to prepare maintenance plans and estimate costs, analyzing the inspection results.

Table-2 Maintenance Procedure for Paved Roads

Step	Tasks to be Taken on	In Charge
Step.1	IRI measurement with visual inspection	RID
Step.2	- Preparation of IRI-based road inventory (Inventory)	RID
	- Analysis on Inventory and identification of defective road sections	RID
	- Preparation of Inspection Review Sheet & analysis on inspection results	RID
	- Instructions to DPWT for visual inspection, based on Inspection Review Sheet	RID
	- Visual inspection by DPWT with Inspection Review Sheet (to be updated)	DPWT
	- Update of Inspection Review Sheet with DPWT inspection results	RID
Step.3	- Preparation of road lists, based on Inventory	RID
	- Prioritization of maintenance plans	RID/DPWT
Step.4	- Selection of maintenance methods	RID/DPWT
	- Preparation of unit prices for work items and cost estimate for maintenance plans	RID/DPWT
Step.5	Budget request (for Chap.61) and negotiation with MEF	RID
Step.6	- Supervision of maintenance works	RID
	- Implementation of maintenance plans	DPWT

1.3.3 Maintenance Procedure for Unpaved Roads

Table-3 gives the road maintenance procedure for unpaved roads. Basically, the procedure is the same as that for paved roads. The difference is that unpaved roads for inspection are selected while all the paved roads are inspection targets. Also, DPWT doesn't carry out detailed visual inspection in Step.2. Instead, DPWT briefly checks the road conditions at the sites, referring to information on Inspection Review Sheet.

Table-3 Maintenance Procedure for Unpaved Roads

Step	Tasks to be Taken on	In Charge
Step.1	- Selection of road sections (maintenance target) for inspection	RID/DPWT
	- IRI measurement with visual inspection	RID
Step.2	- Preparation of IRI-based road inventory (Inventory2)	RID
	- Analysis on Inventory2 and identification of defective road sections	RID
	- Preparation of Inspection Review Sheet and analysis on inspection results	RID
	- Instructions to DPWT for visual inspection, based on Inspection Review Sheet	RID
	- Visual inspection by DPWT with Inspection Review Sheet (to be updated)	DPWT
	- Update of Inspection Review Sheet with DPWT inspection results	RID
Step.3	- Preparation of road lists, based on Inventory2	RID
	- Prioritization of maintenance plans	RID/DPWT
Step.4	- Selection of maintenance methods	RID/DPWT
	- Preparation of unit prices for work items and cost estimate for maintenance plans	RID/DPWT
Step.5	Budget request (for Chap.61) and negotiation with MEF	RID
Step.6	- Supervision of maintenance works	RID
	- Implementation of maintenance plans	DPWT

1.4 Organization of Guidelines for Routine Road Maintenance

A total of 5 documents apply to road maintenance system using IRI. As summarized in Table-4, the 5 documents consist of 4 guidelines and one supplemental document. The relationship between the documents and the maintenance cycle steps is explained in Table-5.

Table-4 The list of Documents for Routine Road Maintenance

Document Type	No.	Name
Guidelines	1	Guidelines for Supervision of Routine Maintenance
	2	Guidelines for Regular Inspection
	3	Guidelines for Repairing Defects
	4	Guidelines for Routine Road Maintenance Using IRI
Supplemental Document	5	Unit prices for routine road maintenance

Table-5 The Relationship between Road Maintenance Cycle Steps and Reference Materials

Step	Maintenance Activity	Documents No. for Reference
1	IRI measurement	No.4
	Visual inspection	No.4
2	Evaluation of inspection results	No.4
	Visual inspection by DPWT for check	No.2
3	Preparation of road lists with evaluation results	No.4
4	Selection of maintenance methods and cost estimate	No.4, No.5
5	Budget Request for Road Maintenance Plans	No.4
6	Implementation of Road Maintenance Plans	No.1, No.3

CHAPTER 2 Step.1: IRI Measurement and Visual Inspection

2.1 Inspection Objective and Items

2.1.1 Inspection Objective

Objective of IRI measurement and visual inspection is to evaluate road surface conditions quantitatively. The inspection results are to be used for maintenance planning and cost estimate of repair plans.

2.1.2 Inspection Items

In order to appropriately assess existing road surface conditions, at least 1) Road roughness (IRI), 2) Cracks, and 3) Potholes shall be closely examined by IRI measurement and visual inspection in Step.1. These 3 inspection items cover evaluation of major defects that affect travel safety and performance of vehicles most; namely, 1) road roughness, 2) cracks, 3) potholes, and 4) deformation. Relationship between the 3 inspection items and the 4 major defects is summarized in Table-6.

Table-6 Relationship between 3 Inspection Items and 4 Major Defects

Inspection Methods	Inspection Items	Major Defects to be Inspected				
		Roughness	Cracks		Potholes	Deformation
			Linear	Alligator		
IRI Measurement	**IRI**	**A**	**B**	**B**	**B**	**C**
Visual Inspection	**Cracks**	**C**	**A**	**A**	**-**	**A**
	Potholes	**C**	**-**	**-**	**A**	**-**

A: the best **B**: applicable **C**: supplemental

2.2 Formation of Inspection Teams

In the guidelines, inspection scheme is described on the condition that inspection teams are formulated with a minimum of 2 members (one driver and one inspector). The inspectors conduct both IRI measurement and visual inspection by themselves. Seat arrangement of the teams is shown in Figure-5.

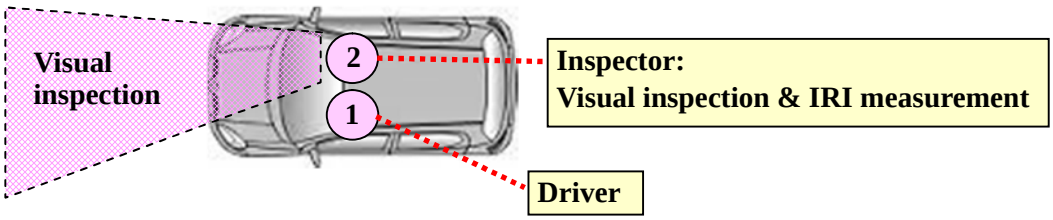


Figure-5 Seat Arrangement of Inspection Teams

2.3 IRI Measurement

2.3.1 Basic Knowledge on IRI

Generally, IRI values range from 1.5 to over 16.0 (calculation interval: 10m), depending on road surface conditions as shown in Figure-6. Practically, road sections with average (ave.) IRI values over 3.5 are likely to need repair works. Especially, road sections with ave. IRI values over 7.0 need urgent repair or reconstruction.

Focusing on the relationship between IRI-value range and vehicle-speed range, it is likely that vehicles typically run at 80km/h under IRI values up to 7.0, and at 100km/h under IRI values up to 3.5.

In consideration of the above analysis, for major national highways such as 1-digit and 2-digit roads, all the road sections should be constantly maintained, targeting IRI values less than 3.5 after repair works.

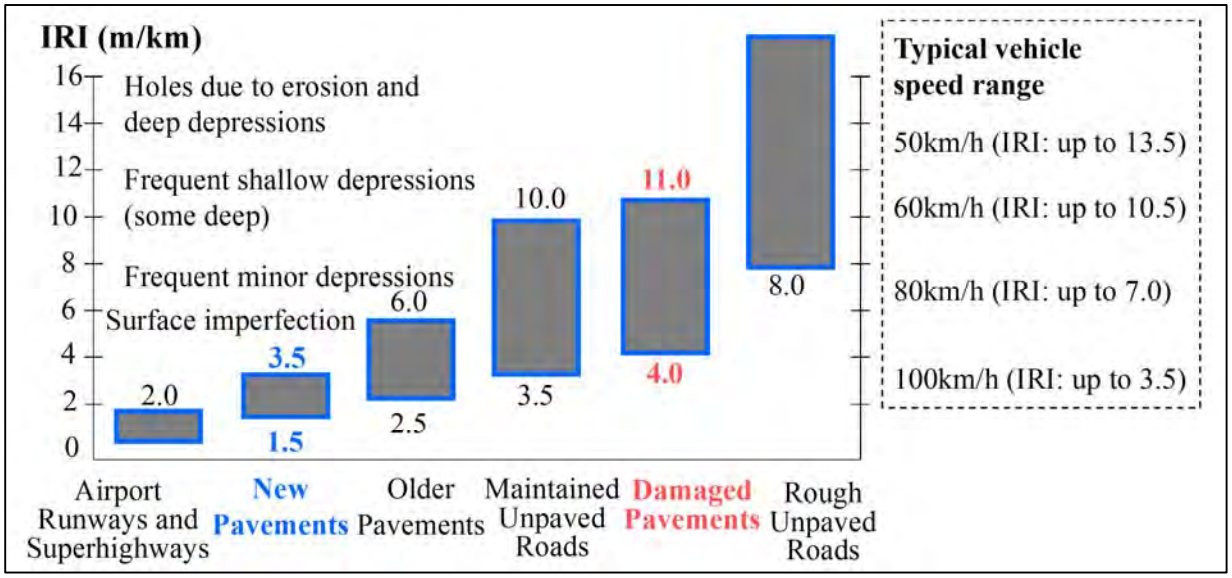


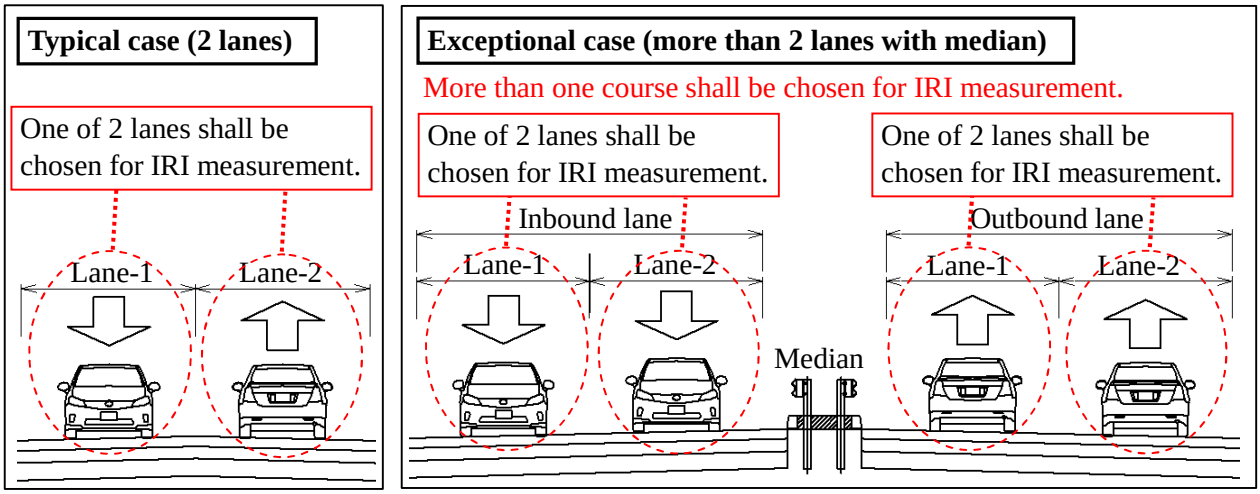
Figure-6 Typical Range of IRI Values (calculation interval: 10m)

2.3.2 Basic Rules for IRI Measurement

(1) Inspection Course

Basically, in Cambodia, the number of lanes is 2 except for a few special roads. Principally, one of the 2 lanes shall be chosen for IRI measurement, as shown in Figure-7. Condition of the other lane shall be examined by visual inspection. In case that target roads for inspection have more than 2 lanes with median, more than one course shall be chosen for IRI measurement; in other words, one inspection course for inbound 2 lanes and the other for outbound 2 lanes.

Moreover, as shown in Figure-8, vehicles for inspection shall not avoid identified defects so that actual road surface conditions can be reflected on inspection results, IRI values. In the case when vehicles are not able to get on the defects, detection of the defects shall be covered by visual inspection.



Note: Condition of the other lane shall be checked by visual inspection.

Figure-7 The Number of Lanes and Inspection Course to be Taken

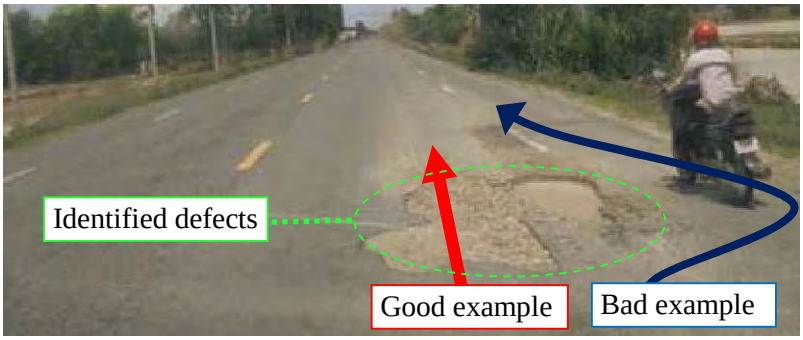


Figure-8 Inspection Course to be Taken

(2) Importance of Cooperation with Visual Inspection

It is very important that IRI measurement and visual inspection should be carried out in cooperation. After obtaining IRI values, inspectors shall visually examine the cause of large IRI values since high IRI values could unusually occur not because of defects, but other causes such as insufficient functioning of bridge expansion joints and protruding lane marks as shown in Figure-9. These unusual cases shall be clearly reported in inspection results.

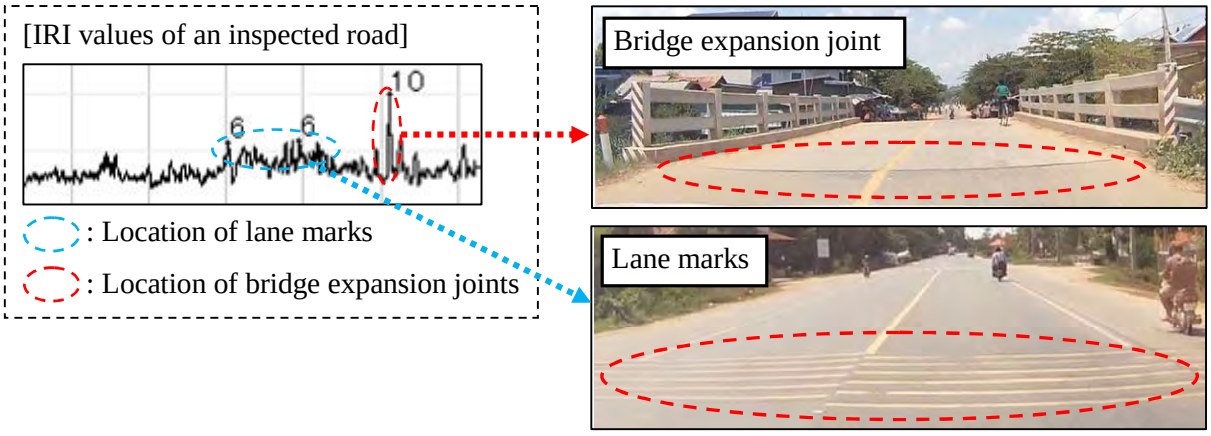


Figure-9 Identification of Large IRI Values at Bridge Expansion Joints & Lane Marks

2.3.3 Equipment for IRI Measurement

IRI measurement shall be carried out with appropriate measurement equipment. In Appendix, application of DRIMS is introduced as an example.

2.4 Visual Inspection

2.4.1 Importance of Visual Inspection

In addition to roughness inspection by IRI measurement, visual inspection shall be carried out properly in order to assess the current road conditions. Evaluation of road conditions with IRI values is a very efficient method. However, defects that are not on the IRI measurement courses could be overlooked if road conditions are judged by only IRI values. Accordingly, in the guidelines, an evaluation system with a combination of IRI values and visual inspection results is suggested.

2.4.2 Visual Inspection

Visual inspection shall be carried out in accordance with the procedure specified in “Guidelines for Regular Inspection”. (Additional inspection rules are specified in “Section 2.4.2” and “Section 3.2.3” of the guidelines.)

As already explained in “Section 2.3.2”, road conditions of the other lanes shall be covered by visual inspection. As shown in Figure-10, the inspectors shall:

1) count the number of major defects at 5.0km intervals and
2) take notes of major findings

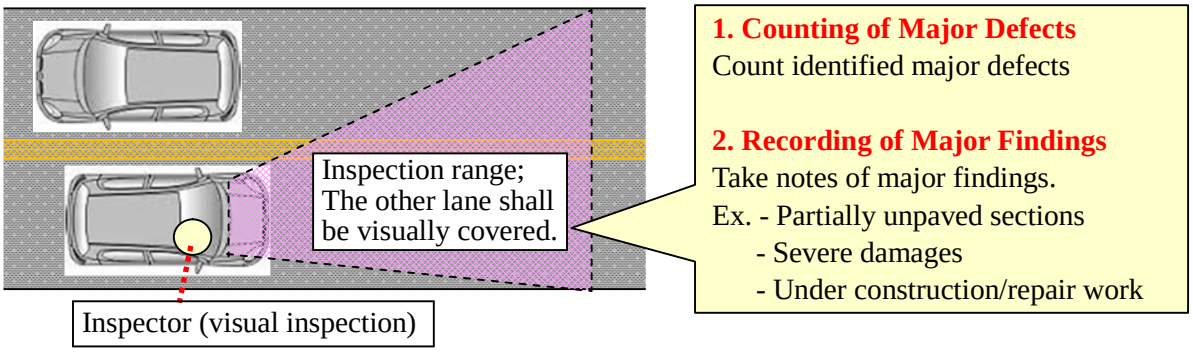


Figure-10 Outline of Visual Inspection

CHAPTER 3 Step.2: Evaluation of Inspection Results

3.1 Outline

Existing road conditions shall be evaluated in Step.2 with the results of IRI measurement and visual inspection. The objectives of the evaluation are 1) to identify road sections that need repair works and 2) to grasp severity of deterioration/damages of the identified road sections. Conditions of paved roads shall be quantitatively evaluated every 5.0km by a combination of IRI measurement results (IRI values) and visual inspection results. In case of unpaved roads, the conditions are quantitatively evaluated every 5.0km by only IRI values for maintenance management efficiency although conditions of the target roads are visually checked during inspections.

3.2 Paved Roads

3.2.1 Road Inventory Format

For inspection data summarization, road Inventory (Inventory) shall be prepared. Preparation of Inventory enables road administrators to see the current road conditions in detail and make planning of road maintenance more efficient. The Inventory consists of 14 items shown in Table-7 and summarizes inspection and evaluation results of the inspected roads. Figure-11 shows the basic format of Inventory.

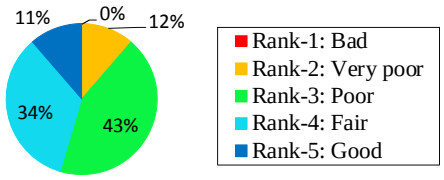
Table-7 Items to be Included in the Road Inventory for Paved Roads

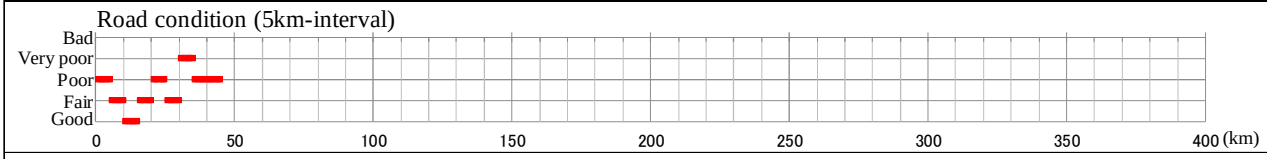
Item		Description
(1) Road Name		Name of inspected roads
(2) Road Length		Total length of inspected roads (km)
(3) Pavement Type		AC, DBST, MCD, unpaved etc.
(4) Date of IRI Measurement		Inspection date
(5) Start Point & End Point		Locations of start points and end points either by: - Kilo Post (PK) or - Name of cities/towns (if the Kilo Post is unknown)
(6) Average IRI (Total Section)		Average (Ave.) IRI value of the entire road sections
(7) Visual Rating (Total Section)		Ave. indicator-N value & evaluation for the entire road sections
(8) Repair Ratio (**Rank-1**+**Rank-2**+**Rank-3**)		Ratio of road sections that need repair; ratio of "Rank-1+Rank-2+Rank-3" (evaluation criteria: refer to "Section 3.2.4")
(9)	Urgency Ratio (**Rank-1**+**Rank-2**)	Ratio of road sections that need urgent repair or reconstruction; ratio of "Rank-1+Rank-2"
	Emergency Ratio (**Rank-1**)	Ratio of road sections that need reconstruction; ratio of "Rank-1"
(10) Location		Locations of IRI measurement (100m intervals)
(11) Average IRI		1) Ave. IRI values at 100m intervals (to be entered in the Inventory) 2) Ave. IRI values at 1.0km intervals (to be calculated automatically) 3) Ave. IRI values at 5.0km intervals (to be calculated automatically)
(12) Visual Rating (per 5.0km)		1) The number of defects at 100m intervals (not required; option) 2) The number of defects at 5.0km intervals (required) 3) Indicator-N value and evaluation results (refer to "Section 3.2.3")
(13) Road condition (per 5.0km)		Evaluation of road conditions at 5.0km intervals (refer to "Section 3.2.4")
(14) Remarks		1) The number of bridge expansion joints at 100m intervals 2) Major findings (from visual inspection results) Ex. - Partially unpaved sections, severe damages - Under construction/repair work

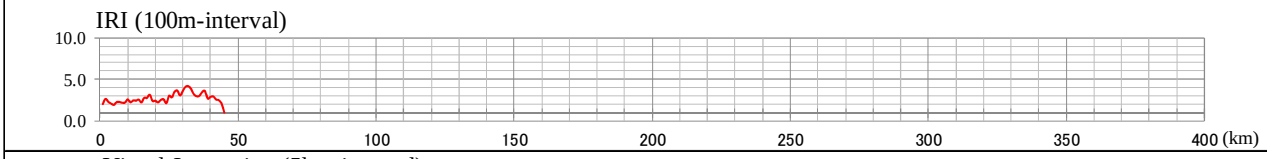
Road Inventory (for Paved Roads)

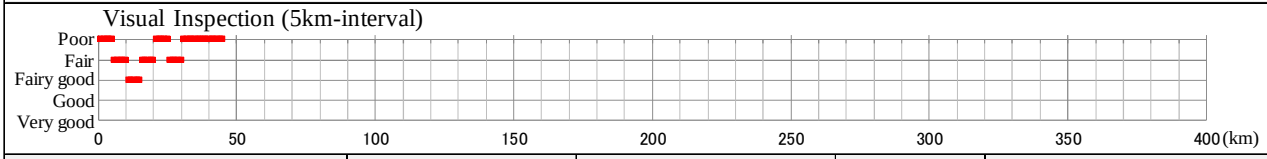
(1)	Road Name	RN1 (Kandal)				
(2)	Road Length (km)	44.0	Inspected road length:	**44.1** km		
(3)	Pavement Type	AC				
(4)	Date of IRI measurement	24/July/2015				
(5)	Start Point & End Point	Start	PK016+500	End	PK060+500	
(6)	Average IRI (Total Section)	2.7				
(7)	Visual Rating (Total Section)	Indicator-N	1.51	Evaluation	Poor	
(8)	Repair Ratio (**Rank-1+Rank-2+Rank-3**)	**54.6%**				
(9)	Urgency Ratio (**Rank-1+Rank-2**)	**11.3%**	Emergency Ratio (**Rank-1**)	**0.0%**		

Breakdown of the Road Condition









(10) Location		(11) Average IRI			(12) Visual Rating (Per 5.0km)				(13) Road Condition (Per 5.0km)	(14) Remarks	
From	To	Per 100m	Per 1.0km	Per 5.0km	No.of Defects Per 100m	No.of Defects Per 5.0km	N	Evaluation		No. of Bridge Joints	Major Findings
0 km + 0	0 km + 100	1.5	2.0	-	0	-	-	-	-	0	
0 km + 100	0 km + 200	1.9			0					0	
0 km + 200	0 km + 300	2.1			0					0	
0 km + 300	0 km + 400	2.0			0					0	
0 km + 400	0 km + 500	1.9			0					0	
0 km + 500	0 km + 600	1.8			0					0	
0 km + 600	0 km + 700	1.7			0					0	
0 km + 700	0 km + 800	2.1			0					0	
0 km + 800	0 km + 900	2.5			0					0	
0 km + 900	1 km + 0	2.6			0					0	
1 km + 0	1 km + 100	2.6	2.7	-	0	-	-	-	-	0	
1 km + 100	1 km + 200	2.6			1					0	
1 km + 200	1 km + 300	2.6			0					0	
1 km + 300	1 km + 400	2.6			1					0	
1 km + 400	1 km + 500	2.8			1					0	
1 km + 500	1 km + 600	2.9			0					0	
1 km + 600	1 km + 700	3.2			0					0	
1 km + 700	1 km + 800	3.0			0					0	
3 km + 300	3 km + 400	2.0	2.1	-	0	-	-	-	-	0	
3 km + 400	3 km + 500	1.8			0					0	
3 km + 500	3 km + 600	2.0			0					0	
3 km + 600	3 km + 700	1.9			0					0	
3 km + 700	3 km + 800	1.7			0					0	
3 km + 800	3 km + 900	1.8			0					0	
3 km + 900	4 km + 0	1.9			0					0	
4 km + 0	4 km + 100	1.8	1.9	2.2	0	15	3.00	Poor	Rank-3: Poor	0	
4 km + 100	4 km + 200	2.0			0					0	
4 km + 200	4 km + 300	2.0			1					0	
4 km + 300	4 km + 400	1.9			1					0	
4 km + 400	4 km + 500	1.8			0					0	
4 km + 500	4 km + 600	1.7			0					0	
4 km + 600	4 km + 700	1.8			0				Repair (moderate)	0	
4 km + 700	4 km + 800	1.8			0					1	
4 km + 800	4 km + 900	2.1			0					0	
4 km + 900	5 km + 0	2.1			0					0	

[Definition of Color Indication]

10.0≦IRI
7.0≦IRI<10.0
5.0≦IRI<7.0
3.0≦IRI<5.0
IRI<3.0

Comments from visual inspection

Roads shall be evaluated every 5.0km. The evaluation of each 5.0km-section is shown in the last 1.0km-section.

Figure-11 Road Inventory Format for Paved Roads

3.2.2 Summarization of IRI Measurement Results

Ave. IRI values shall be calculated at 100m intervals, based on IRI measurement results. The calculated data is to be entered in “Per 100m” column of “(11) Average IRI” in the Inventory. After completion of the data entry for “Per 100m” column, the other 2 columns for ave. IRI-value (per 1.0km & 5.0km) will be calculated automatically.

3.2.3 Visual Rating

(1) Visual Rating of Major Defects

Road surface conditions shall be visually rated at 5.0km intervals, based on the number of major defects counted in inspections. The road conditions are evaluated by the following formula with the number of major defects shown in Figure-12.

N= (The number of major defects) / (road length of 5km)

Where,

N: The indicator for evaluation of visual inspection (indicator-N)

(The number of major defects): The number of major defects shown below within 5.0km

(Road length): 5.0km (evaluation interval)

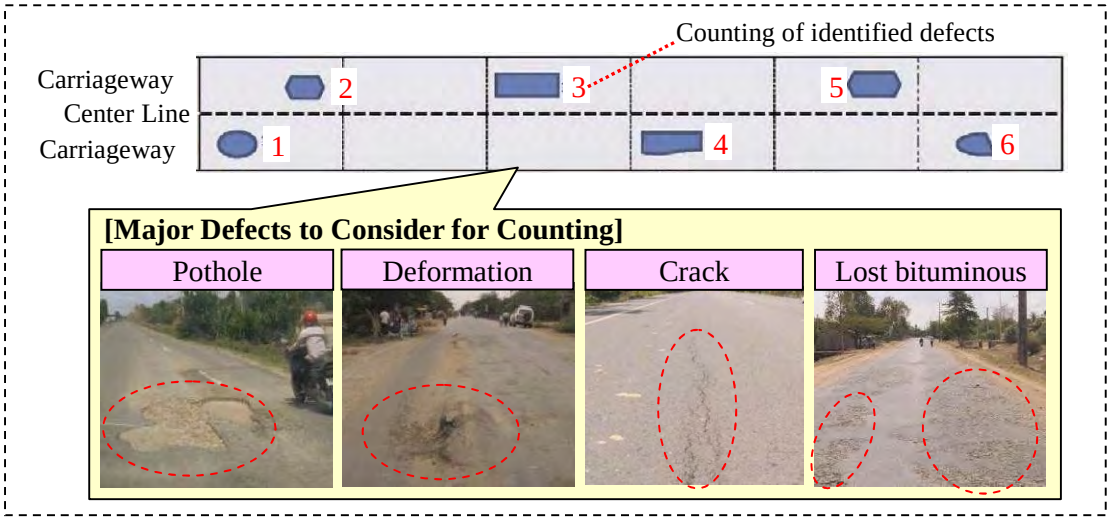


Figure-12 Evaluation Scheme of Visual Inspection

The number of defects are to be entered in “Per 100m” column of “(12) Visual Rating” in the Inventory. After completion of the data entry for “Per 100m” column, indicator-N values and evaluation will be displayed automatically. The relationship between the indicator-N and evaluation of the visual inspection is shown in Table-8.

Table-8 Relationship between Indicator-N and Evaluation of Visual Inspection

Indicator-N	Evaluation
$0 \leq N < 0.2$	Very good
$0.2 \leq N < 0.4$	Good
$0.4 \leq N < 0.6$	Fairy good
$0.6 \leq N < 1.15$	Fair
$1.15 < N$	Poor

(2) Recording of Bridge Expansion Joints and Major Findings

Besides counting of major defects for visual rating, location of bridge expansion joints and major findings shall be recorded in "(14) Remarks" in the Inventory. The "major findings" are defined as follows.

1) Descriptions on severe road conditions due to major defects
   Ex. severe damages, partially unpaved etc.
2) Information on ongoing projects
   Ex. Under construction/repair work
3) Identification of minor defects on the road sides
   Ex. Minor defects on the road sides such as dragon holes, deformation etc.
   Note: If these defects are counted as major defects, there's no need to record the above findings.

3.2.4 Overall Evaluation of Inspection Results

Conditions of the inspected roads shall be comprehensively evaluated by combination of IRI values and visual rating results in order to accurately identify road sections that need maintenance measures. Criteria shown in Table-9 shall be applied for the evaluation. The road conditions are to be classified into 5 ranks according to IRI values and visual rating results.

Table-9 Evaluation Criteria for Road conditions

<table>
<tr><th>Visual Rating
IRI (5km-ave.)</th><th>Very good</th><th>Good</th><th>Fairy Good</th><th>Fair</th><th>Poor</th></tr>
<tr><td>IRI<3.5</td><td colspan="3">Rank-5: Good
(No or small repair)</td><td>Rank-4: Fair
(Small repair)</td><td>Rank-3: Poor
(Repair)</td></tr>
<tr><td>3.5 ≤ IRI<5.0</td><td colspan="3">Rank-3: Poor
(Repair)</td><td colspan="2">Rank-2: Very poor
(Severe repair)</td></tr>
<tr><td>5.0 ≤ IRI</td><td colspan="5">Rank-1: Bad
(Reconstruction/Rehabilitation/Upgrade)</td></tr>
</table>

Note: Calculation interval of ave. IRI-value is 5.0km.

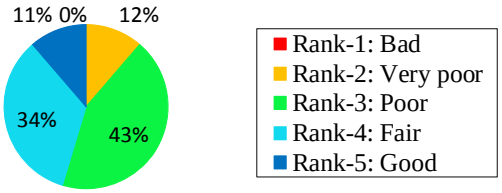
3.2.5 Preparation of Inspection Review Sheet

Information on Inventory is to be summarized in "Inspection Review Sheet" shown in Figure-13. RID analyzes the inspection results with the sheet and gives DPWT instructions for detailed visual inspection. DPWT is to update the sheet with their visual inspection results.

Inspection Review Sheet (for Paved Roads)

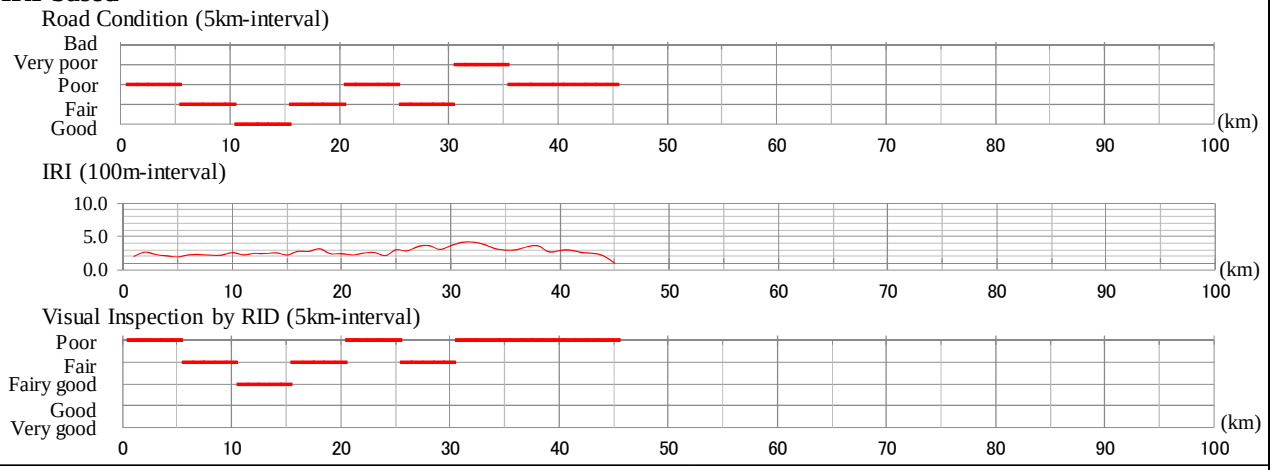
(1)	Road Name	RN1 (Kandal)	
(2)	Road Length (km) (Inspected: 44.1(km))		44.0
(3)	Pavement Type		AC
(4)	Date of IRI measurement		24/July/2015
(5)	Start Point & End Point	Start	PK016+500
		End	PK060+500
(6)	Average IRI (Total Section)		2.7
(7)	Visual Rating (Total Section)	Indicator-N	1.51
		Evaluation	Poor
(8)	Repair Ratio (Rank-1+Rank-2+Rank-3)		**54.6%**
(9)	Urgency Ratio (Rank-1+Rank-2)		**11.3%**

Breakdown of Road Condition

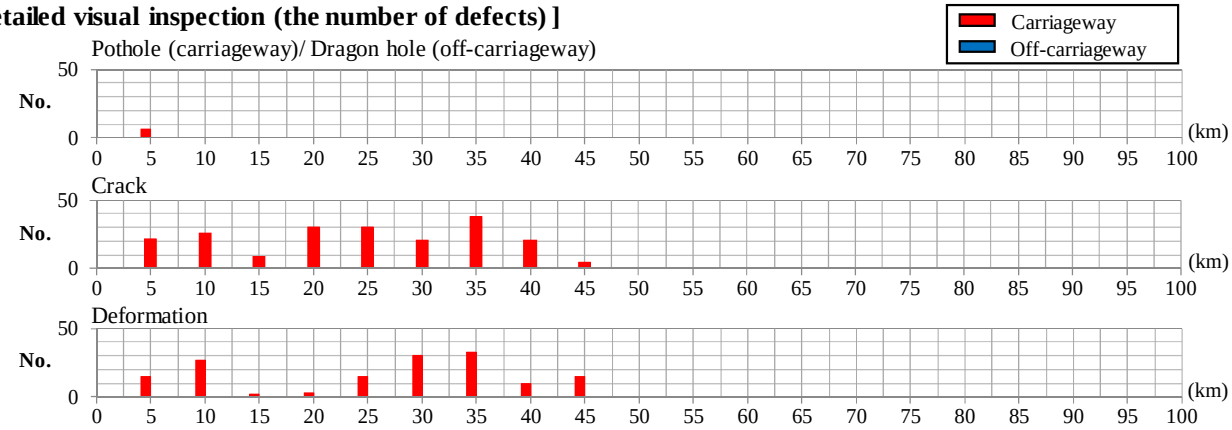


Emergency Ratio (Rank-1)	**0.0%**

[IRI-based



[Detailed visual inspection (the number of defects)]



Location				IRI-based inspection					Visual inspection for check					
							Road condition		Carriageway			Off-carriageway		
From		To		Ave. IRI	Visual rating		Rank: Condition	Discription	Pot-hole	Crack	Defor-mation	Defor-mation	Dragon hole	Update
km	PK	km	PK		N	Evaluation								
0	16.5	**5**	21.5	2.19	3.00	Poor	**3:Poor**	Repair (moderate)	6	22	15			
5	21.5	**10**	26.5	2.30	0.80	Fair	**4:Fair**	Repair (small)		26	27			☑
10	26.5	**15**	31.5	2.38	0.40	Fairly good	**5:Good**	Regular inspection		9	2			
15	31.5	**20**	36.5	2.70	1.00	Fair	**4:Fair**	Repair (small)		30	3			
20	36.5	**25**	41.5	2.50	2.20	Poor	**3:Poor**	Repair (moderate)		30	15			
25	41.5	**30**	46.5	3.33	0.60	Fair	**4:Fair**	Repair (small)		21	30			
30	46.5	**35**	51.5	3.65	2.20	Poor	**2:Very poor**	Repair/ Resurfacing		38	33			
35	51.5	**40**	56.5	3.13	1.20	Poor	**3:Poor**	Repair (moderate)		21	10			
40	56.5	**45**	61.5	2.22	2.20	Poor	**3:Poor**	Repair (moderate)		5	15			
45	61.5	**50**	66.5											

If visual rating is updated based on visual inspection after IRI measurement, mark ☑.

In case that visual rating is updated based on visual inspection results after IRI measurement, mark ☑ in "Update" column.

Enter the number of defects detected in visual inspection after IRI measurement

Figure-13 Inspection Review Sheet for Paved Roads

3.3 Unpaved Roads

3.3.1 Road Inventory Format

As well as paved roads, inspection data of unpaved roads is to be summarized as road Inventory (Inventory2). The Inventory consists of 11 items shown in Table-10 and summarizes inspection and evaluation results of the inspected roads. Figure-15 shows the basic format of Inventory2. In contrast to paved roads, conditions of unpaved roads are quantitatively evaluated with IRI values only. Although visual rating criteria for unpaved roads are not specifically set, the conditions are checked and the major findings should be recorded in the Inventory. Information on Inventory2 is to be summarized in "Inspection Review Sheet" shown in Figure-16 that is to be updated by DPWT with their inspection results.

Table-10 Items to be Included in the Road Inventory for Unpaved Roads (Inventory2)

Item	Description
(1) Road Name	Name of inspected roads
(2) Road Length	Total length of inspected roads (km)
(3) Pavement Type	AC, DBST, MCD, unpaved etc.
(4) Date of IRI Measurement	Inspection date
(5) Start Point & End Point	Locations of start points and end points either by: - Kilo Post (PK) or - Name of cities/towns (if the Kilo Post is unknown)
(6) Average IRI (Total Section)	Average (Ave.) IRI value of the entire road sections
(7) Repair Ratio	Ratio of road sections that need repair
(8) Location	Location of IRI measurement (100m intervals)
(9) Average IRI	1) Ave. IRI values at 100m intervals (to be entered in the Inventory) 2) Ave. IRI values at 1.0km intervals (to be calculated automatically) 3) Ave. IRI values at 5.0km intervals (to be calculated automatically)
(10) Road condition (per 5.0km)	Evaluation of road conditions at 5.0km intervals (See "Section 3.3.2")
(11) Remarks	1) The number of bridge expansion joints at 100m intervals 2) Major findings (from visual inspection results) Ex. - Severe damages - Under construction/repair work

3.3.2 Evaluation of Inspection Results

Repair necessity of unpaved roads is to be judged by the following criteria. Calculation interval of ave. IRI values is 5.0km as well as that for paved roads.

1) IRI<5.0 (No repair): Routine inspection

2) 5.0≤IRI (Repair): Repair (Ex. grading/leveling; see Figure-14)

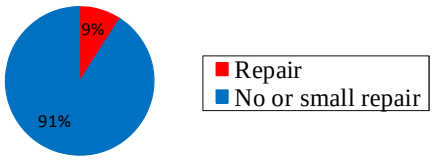
Note: Calculation interval of ave. IRI-value is 5.0km.

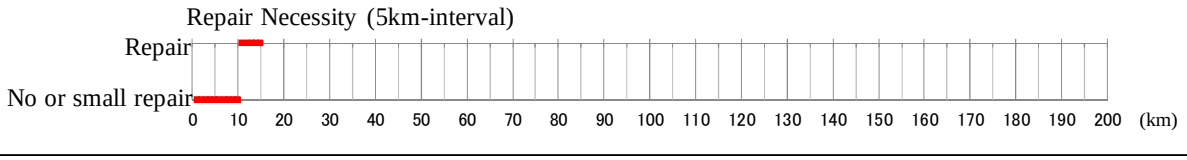
Figure-14 Grading for Unpaved Roads

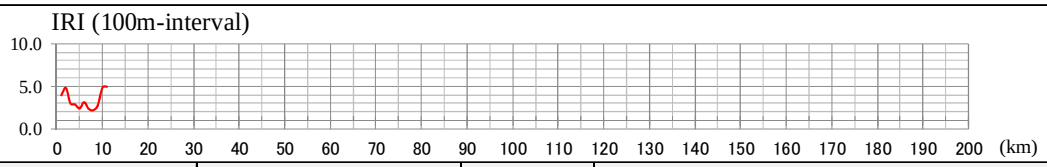
Road Inventory2 (for Unpaved Roads)

(1)	Road Name	RN383			
(2)	Road Length (km)	8.4	Inspected road length:	10.8 (km)	
(3)	Pavement Type	Laterite			
(4)	Date of IRI measurement	3/June/2016			
(5)	Start Point & End Point	Start PK000+000	End	PK008+350	
(6)	Average IRI (Total Section)	3.4			
(7)	Repair Ratio (5.0<IRI)	9.1%			

Breakdown of Road Condition







(8) Location		(9) Average IRI			(10) Priority (Per 5.0km)	(11) Remarks	
From	To	Per 100m	Per 1.0km	Per 5.0km		No. of Bridge Joints	Major Findings
0 km + 0	0 km + 100	3.8				0	
0 km + 100	0 km + 200	2.9				0	
0 km + 200	0 km + 300	2.1				0	
0 km + 300	0 km + 400	2.5				0	
0 km + 400	0 km + 500	3.3				0	
0 km + 500	0 km + 600	4.0	3.9	-	-	0	
0 km + 600	0 km + 700	4.9				0	
0 km + 700	0 km + 800	6.3				2	
0 km + 800	0 km + 900	5.8					
0 km + 900	1 km + 0	4.0					
1 km + 0	1 km + 100	4.7					
1 km + 100	1 km + 200	6.5					
1 km + 200	1 km + 300	5.0					
1 km + 300	1 km + 400	3.6					
1 km + 400	1 km + 500	3.5					
1 km + 500	1 km + 600	4.8	4.8				
1 km + 600	1 km + 700	7.5					
1 km + 700	1 km + 800	5.0					
1 km + 800	1 km + 900	3.8				0	
1 km + 900	2 km + 0	3.5				0	
3 km + 200	3 km + 300	2.5				0	
3 km + 300	3 km + 400	2.2				0	
3 km + 400	3 km + 500	2.1				0	
3 km + 500	3 km + 600	2.6	2.9	-	-	0	
3 km + 600	3 km + 700	3.2				0	
3 km + 700	3 km + 800	3.6				0	
3 km + 800	3 km + 900	3.3				0	
3 km + 900	4 km + 0	2.8				0	
4 km + 0	4 km + 100	2.6				0	
4 km + 100	4 km + 200	2.4				0	
4 km + 200	4 km + 300	2.3				0	
4 km + 300	4 km + 400	2.8				0	
4 km + 400	4 km + 500	2.9				0	
4 km + 500	4 km + 600	2.0	2.4	3.4	No repair	0	
4 km + 600	4 km + 700	2.1				0	
4 km + 700	4 km + 800	2.3				0	
4 km + 800	4 km + 900	2.3				0	
4 km + 900	5 km + 0	2.2				0	

[Definition of Color Indication]

- 10.0≦IRI
- 7.0≦IRI<10.0
- 5.0≦IRI<7.0
- 3.0≦IRI<5.0
- IRI<3.0

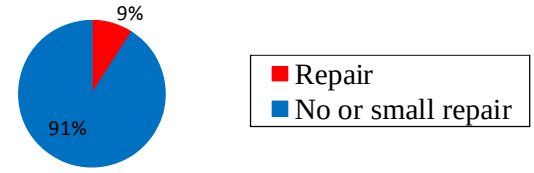
Comments from visual inspection

Roads shall be evaluated every 5.0km. The evaluation of each 5.0km-section is shown in the last 1.0km-section.

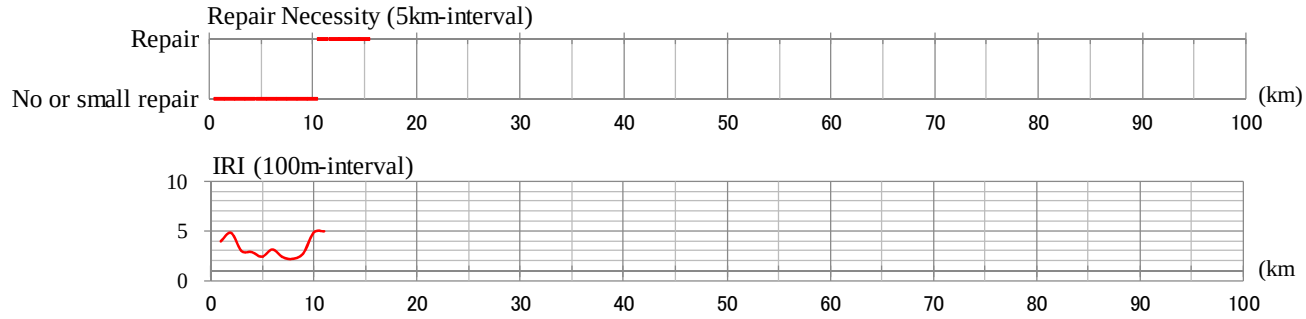
Figure-15 Road Inventory Format for Unpaved Roads

Inspection Review Sheet (for Unpaved Roads)

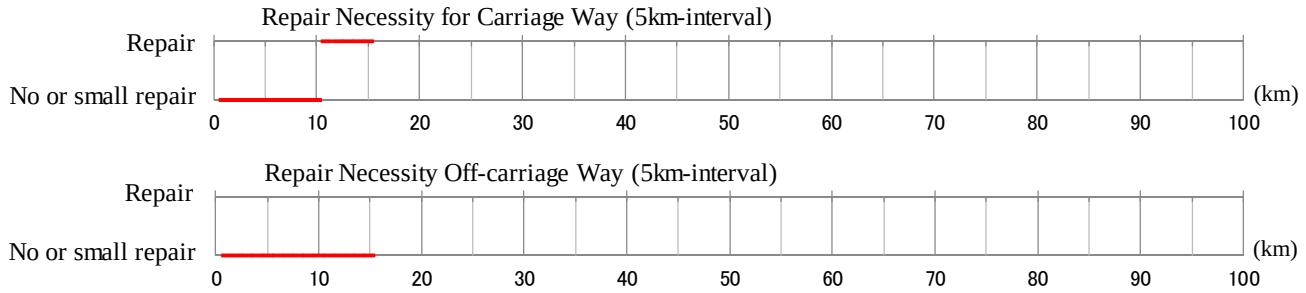
				Breakdown of Road Condition
(1)	Road Name		RN383	
(2)	Road Length (km) (Inspected: 10.8(km))		8.4	
(3)	Pavement Type		Laterite	
(4)	Date of IRI measurement		3/June/2016	
(5)	Start Point & End Point	Start	PK000+000	
		End	PK008+350	
(6)	Average IRI (Total Section)		3.4	
(7)	Repair Ratio		**9.1%**	



[IRI-based inspection]



[Visual inspection for check]



Location				DRIMS-based inspection		Visual inspection for check		
From		To		Ave. IRI	Repar Necessity	Repar Necessity		Remarks
km	PK	**km**	PK			Carriage way	Off-carriage way	
0	0.0	**5**	5.0	3.4	No repair	No/small repair	No/small repair	
5	5.0	**10**	10.0	3.0	No repair	No/small repair	No/small repair	
10	10.0	**15**	15.0	4.9	Repair	Repair	No/small repair	
15	15.0	**20**	20.0					
20	20.0	**25**	25.0					

Report the repair necessity based on detailed visual inspection results.

Figure-16 Inspection Review Sheet for Unpaved Roads

CHAPTER 4 Step.3: Preparation of Road Lists with Evaluation Results

4.1 Objective of Road List Preparation

Road lists shall be prepared in Step.3 with basic information and evaluation results of the inspected roads. The objective of road list preparation is to summarize current conditions of the inspected roads and prioritize maintenance plans for the listed roads.

4.2 Road List Format

4.2.1 Items to be Included in Road Lists

Road lists shall have basic information such as:

- Road names
- Pavement types (AC, DBST, MCD, unpaved, etc.)
- Length of inspected road sections (km)

Also, the road lists shall include information on road conditions such as:

- Ave. IRI-value of the entire road sections
- Visual rating results of the entire road sections
- Overall evaluation results such as “Repair Ratio” and “Urgency Ratio”.

Additionally, maintenance costs shall be added in the lists after planning and cost estimate of maintenance plans in Step.4.

4.2.2 Prioritization of Road Maintenance Necessity

(1) Outline of Prioritization Criteria

Road maintenance necessity shall be assessed by 3 prioritization criteria (Criteria-A, B, and C) shown in Table-11. While Criteria-A and B are relevant to road importance that is given as precondition, Criteria-C is set for assessment of road conditions that are fluctuating factors. Target roads for maintenance works are to be comprehensively prioritized after evaluation of inspection results.

Table-11 Prioritization Criteria for Road Maintenance Necessity

		Criteria-A: Road Classification	Criteria-B: Road Importance	Criteria-C: Road conditions
Prioritization Index		Digit class of roads	- Road necessity - AADT (Annual Average Daily Traffic)	Classification of road conditions by combination of IRI and visual rating (See Table-9)
Priority (Necessity)	High ↕ Low	1-digit roads 2-digit roads 3-digit roads 4-digit roads	Large traffic volume Small traffic volume	Rank-1: Bad Rank-2: Very poor Rank-3: Poor Rank-4: Fair Rank-5: Good

(2) Criteria A: Road Classification (by digit-class)

The entire road network is classified into 4 road importance ranks called “digit-class” as shown in Table-12; namely, 1-digit (the highest class), 2-digit, 3-digit, and 4-digit (the lowest class) roads. The maintenance necessity is principally determined based on the digit-class.

Table-12 Criteria-A: Road Classification by 4 digit-classes

Road Class	Priority
1-digit roads	High
2-digit roads	⇕
3-digit roads	
4-digit roads	Low

(3) Criteria-B: Road Importance

Criteria-B is applied for classification of road importance by 1) road necessity in the entire road network and 2) Annual Average Daily Traffic (AADT). The classification scheme is sited from the master plan prepared by MPWT with assistance of JICA (Project name: Data Collection Survey on the Trunk Road Network Planning for Strengthening of Connectivity through the Southern Economic Corridor). Details of the classification are shown in Table-13 (See the columns named “Criteria-B: Road Importance” and “Reasons for Road Importance”).

(4) Criteria-C: Road conditions

Besides the prioritization of roads by Criteria-A & B, maintenance necessity of the target roads are prioritized by Criteria-C that set is for evaluation of road conditions shown in Table-9. Roads with:

1) high “Repair Ratio (Rank-1+Rank-2+Rank-3)”,
2) high “Urgency Ratio (Rank-2+Rank-3)”, and
3) high “Emergency Ratio (Rank-1)”

shall be prioritized.

(5) Overall Prioritization of Road Maintenance Plans

Overall prioritization of road maintenance plans shall be carried out according to the maintenance necessity criteria table summarized in Table-13. Inspection results are to be applied as “Criteria-C: Road conditions”.

(6) Road List Format

An example of the road list format is shown in Table-14. The road lists shall be prepared province by province.

Table-13 Overall Prioritization Criteria for Road Maintenance Plans

Maintenance Priority			Road Name	Reasons for Road Importance defined as Criteria-B
Criteria-A: Digit-class	Criteria-B: Road Importance	Criteria-C: Road Conditions		
1	1		1	Asian Highway 1, International Corridor
			4	Connecting international port Sihanouk and Phnom Penh (PP)
			5	Asian Highway 1, International Corridor
	2		2	Connecting Vietnam border and PP
			6	Connecting PP and Siem Reap (the biggest tourism city)
			7	Connecting Laos border and PP
	3		3	Detour for the connection of PP to Sihanouk
			8	1-digit road
			9	1-digit road
2			20	Part of the PP ring road
			21*	Part of the PP ring road
			42	Part of the PP ring road
			51	Part of the PP ring road
			61	Part of the PP ring road
			11	Cross-cutting NR1, NR8, and NR7
			73	Shortcut of NR7
			76	Connecting Mondul Kiri and NR7
			78	Connecting Rattanak Kiri and NR7
			64	Connecting Preah Vihear and NR6
			68	Connecting Oddar Meanchey and NR6
			57	Connecting Pailin and NR5
			48	Connecting Koh Kong and NR4
	4		55	Connecting Thailand border and NR5
			62	Connecting Laos border and NR6 via Preah Vihear
			76	Connecting Rattanak Kiri and Mondul Kiri
	5		Other 2-digit roads	
3, 4	6		3- and 4-digit roads	

* National road number 21 (NR21) includes the road sections with branch numbers/letters such as NR21A.
Note: Prioritization by “Criteria-C (Road conditions)” is to be finalized based on inspection results.

Table-14 An Example of the Road List Preparation

Criteria-A: Digit-class

Criteria-B: Road importance

Criteria-C: Road conditions

0≤N<0.2: Very good
0.2≤N<0.4: Good
0.4≤N<0.6: Fairy good
0.6≤N<1.15: Fair
1.15<N: Poor

Rank-1+ Rank-2+ Rank-3

Rank-1+ Rank-2

Rank-1

Maintenance cost for maintenance works categorized as Chap.61
The cost is to be estimated in Step.4

Other Costs:
(Off-carriageway)+(Structures)+(Road furniture)

Project Priority			Road Name	No. of Lanes	Pavement Type	Inspected Length (km)	Overall Condition		Repair Neccessity (%)			Investment (Chap.21) (%)	Maintenance Cost*4					
													Carriageway		Other Costs*5		Total	
A*	B*	C*					Ave. IRI	Indicator-N (visual rating)	Repair Ratio*1 Rank-1&2&3	Urgency Ratio*2 Rank-1&2	Emergency Ratio*3 Rank-1		($)	($/km)	($)	($/km)	($)	($/km)
1	1	1	NR1	2	AC	44.0	2.71	1.51: Poor	54.6	11.3	0.0	0.0	120,870	2,747	45,983	1,044	166,854	3,791
		2	NR5	2	AC	8.9	2.69	0.3: Good	0.0	0.0	0.0	0.0	12,422	1,396	9,247	1,038	21,669	2,434
		3	NR4	4	AC	11.6	2.08	0: Very good	0.0	0.0	0.0	0.0	31,851	2,746	12,144	1,045	43,995	3,791
	2	-	NR2	2	MCD	19.6	2.70	1.15: Poor	23.5	0.0	0.0	0.0	36,923	1,884	20,504	1,044	57,428	2,928
	3	1	NR3	2	DBST	12.0	2.64	0.8: Fair	41.7	0.0	0.0	0.0	27,360	2,280	12,541	1,044	39,901	3,324
		2	NR8	2	AC	19.9	2.55	1.15: Poor	25.1	0.0	0.0	0.0	40,012	2,011	20,821	1,045	60,832	3,056
2		3	NR21A	2	AC	20.1	2.76	1.1: Fair	50.0	0.0	0.0	0.0	51,042	2,539	17,433	866	68,475	3,405
	5	-	NR14	2	AC	42.5	4.51	10.86: Poor	100.0	76.4	35.4	0.0	253,575	5,966	36,833	865	290,409	6,831
3	6	1	PR110	2	DBST	78.1	3.9	19.97: Poor	51.2	44.8	25.6	0.0	303,147	3,882	45,708	584	348,855	4,466
		2	PR151A	2	DBST	7.7	3.57	0.3: Good	27.5	0.0	0.0	0.0	15,218	1,976	4,562	592	19,781	2,568
		3	PR120	2	AC	6.7	2.29	0.3: Good	0.0	0.0	0.0	0.0	9,348	1,395	3,881	577	13,230	1,972
		4	PR261	2	DBST	22.0	1.92	0.04: Very good	0.0	0.0	0.0	0.0	30,859	1,403	12,872	584	43,731	1,987
		5	PR383	2	Laterite	8.4	3.4	-	9.1	-	-	-	3,694	440	4,932	586	8,626	1,026
					Total:	301.5										Total:	1,183,785	3,926

A*: Road classification by "digit class"
B*: Road importance based on road network and traffic volume
C*: Road conditions
1*: "Repair ratio" is ratio of "Rank-1+ Rank-2+ Rank-3" to inspected road length.
2*: "Urgency ratio" is ratio of "Rank-1+ Rank-2" to inspected road length.
3*: "Emergency Ratio" is the ratio of "Rank-1" to inspected road length.
4*: Maintenance cost (Chap.61): Routine road mainetenance cost
5*: (Off-carriageway)+(Structures)+(Road furniture)

IRI (5km-ave.) \ Visual Rating	Very good	Good	Fairy Good	Fair	Poor
IRI<3.5	Rank-5: Good (No or small repair)			Rank-4: Fair (Small repair)	Rank-3: Poor (Repair)
3.5≤IRI<5.0	Rank-3: Poor (Repair)			Rank-2: Very poor (Severe repair)	
5.0≤IRI	Rank-1: Bad (Reconstruction/Rehabilitation/Upgrade)				

CHAPTER 5 Step.4: Selection of Maintenance Methods and Cost Estimate

5.1 Outline

Approximate maintenance plans and costs shall be prepared in Step.4. The maintenance planning and cost estimation should be done at 5.0km intervals for maintenance management efficiency. Approximate maintenance costs under Chap.61 can be obtained by summing cost estimates of all the 5.0km-sections. Additionally, in case of paved roads, there are 2 options for maintenance of road sections evaluated as "Rank-1 (Bad)", either 1) maintenance planning under Chap.61 or 2) under Chap.21. A standardized cost estimation system for maintenance plans under Chap.61 is suggested here in order to streamline the cost estimation procedure. In the standardized system, maintenance costs consist of 4 cost estimate groups: 1) carriageways, 2) off-carriageway, 3) structures, and 4) road furniture.

5.2 Cost Estimation System for Carriageways of Paved Roads

5.2.1 Selection of Maintenance Methods for Carriageways

(1) Conditions for Selection of Maintenance Methods

Prior to selection of maintenance methods, the following 3 conditions have to be clarified:

1) Existing pavement types
2) Periodical maintenance intervention
3) Large traffic volume range (LV-AADT: Large Vehicle Annual Average Daily Traffic)

Table-15 summarizes the relationship of the above 3 items. In case that LV-AADT is larger than the specified range, maintenance methods for highly ranked roads should be chosen. For example, if the existing pavement type is DBST and LV-AADT is over 500, the pavement type should be upgraded to AC.

Table-15 Conditions for Selection of Maintenance Methods

Existing pavement type	**SBST**	**DBST**	**AC**
Periodical maintenance intervention	3 years	5 years	10 years
Large vehicle traffic volume (LV-AADT*)	(LV-AADT) <200	200< (LV-AADT) <500	500< (LV-AADT)

*LV-AADT: Large Vehicle Annual Average Daily Traffic

(2) Standard Maintenance Methods

Standard maintenance methods are defined for each existing pavement types (SBST, DBST, and AC). Optimal maintenance methods shall be selected according to 5 road condition ranks. Relationship between 5 road condition ranks and standard maintenance methods is shown in Table-16.

Table-16 Standard Maintenance Methods for Each Road condition Rank

Road Condtion	Method	Maintenance Category		Standard Maintenance Methods for Each Existing Pavement Type		
				SBST	DBST	AC
Rank-1: Bad	1	Chap.21	Invest-ment	Reconstruction (SBST)/ Upgrade to DBST or AC	Reconstruction (DBST) Upgrade to AC	Overlay with AC/ Reconstruction (AC)
	2	Chap.61	Routine	Repair (very severe) by DBST		Repair (very severe) by AC
	3		Periodic	Resurfacing/Overlay		
Rank-2: Very poor	1	Chap.61	Routine	Repair (severe) by DBST		Repair (severe) by AC
	2		Periodic	Resurfacing/Overlay		
Rank-3: Poor	1	Chap.61	Routine	Repair (modest) by DBST		Repair (modest) by AC
	2		Periodic	Resurfacing/Overlay		
Rank-4: Fair	-	Chap.61	Routine	Regular inspection/ Preventive maintenance by DBST		Regular inspection/ Preventive maintenance by AC
Rank-5: Good	-	Chap.61				

Chap.21: Investment (Reconstruction/ rehabilitation (upgrade))
Chap.61: Routine Maintenance and Periodic Maintenance
In case that LV-AADT is beyond the specified range, maintenance methods for highly ranked roads should be chosen.

5.2.2 Cost Estimation Scheme

(1) Standard Maintenance Methods and the Cost Estimation Scheme for Carriageways

Costs of each standard method for carriageways shall be estimated in accordance with Table-17. Costs of maintenance methods under Chap.61 are estimated with preliminarily defined unit costs (per 1.0km) while those under Chap.21 are estimated based on bill of quantities (BOQ) prepared in detailed designs.

[Investment (Chap.21)]

If the maintenance method for road sections whose road condition is evaluated to be Rank-1 (Bad), the road sections are to be excluded from maintenance planning under Chap.61, and taken over by maintenance under Chap.21 for reconstruction.

[Routine Maintenance (Chap.61)]

Unit costs for the routine maintenance method under Chap.61 are defined with the following 3 major work code items that are frequently applied to repair of carriageways:

1) Crack sealing (work code: 1131)
2) Shape correction (work code: 1150)
3) Pothole patching (work code: 1161 for DBST, 1100 for AC)

The above cost estimation scheme for routine maintenance can be applied, together with the standardized repair quantities for each damage condition, to all the 5 road condition ranks

[Periodic Maintenance (Chap.61)]

Unit costs for the periodic maintenance method under Chap.61 are defined with overlay. The cost estimation scheme for periodic maintenance can be applied to Rank-1(Bad), Rank-2 (Very poor), and Rank-3 (Poor) that need large-scale repair work. Cost estimators need to specify the specific road section length for overlay.

Table-17 Standard Maintenance Methods and the Cost Estimation Scheme for Carriageways

Road Condtion	Method	Maintenance Category		Standard Maintenance Methods for Each Existing Pavement Type		
				SBST	DBST	AC
Rank-1: Bad	1	Chap.21	Invest-ment	Reconstruction (SBST)/ Upgrade to DBST or AC	Reconstruction (DBST)/ Upgrade to AC	Overlay with AC/ Reconstruction (AC)
				Cost based on bill of quantities (BOQ)		
	2	Chap.61	Routine	Repair (very severe) by DBST: - Crack sealing (1131) - Shape correction (1150) - Pothole patching (1161)		Repair (very severe) by AC: - Crack sealing (1131) - Shape correction (1150) - Pothole patching (1100)
				Unit cost (US$/km)		
	3		Periodic	Resurfacing/Overlay		
				Unit cost (US$/km)		
Rank-2: Very poor	1	Chap.61	Routine	Repair (severe) by DBST: - Crack sealing (1131) - Shape correction (1150) - Pothole patching (1161)		Repair (severe) by AC: - Crack sealing (1131) - Shape correction (1150) - Pothole patching (1100)
				Unit cost (US$/km)		
	2		Periodic	Resurfacing/Overlay		
				Unit cost (US$/km)		
Rank-3: Ppoor	1	Chap.61	Routine	Repair (modest) by DBST: - Crack sealing (1131) - Shape correction (1150) - Pothole patching (1161)		Repair (modest) by AC: - Crack sealing (1131) - Shape correction (1150) - Pothole patching (1100)
				Unit cost (US$/km)		
	2		Periodic	Resurfacing/Overlay		
				Unit cost (US$/km)		
Rank-4: Fair	-	Chap.61	Routine	Repair (small) by DBST: - Crack sealing (1131) - Shape correction (1150) - Pothole patching (1161)		Repair (small) by AC: - Crack sealing (1131) - Shape correction (1150) - Pothole patching (1100)
Rank-5: Good	-	Chap.61				
				Unit cost (US$/km)		

(2) Unit Costs of Standard Maintenance Methods for Carriageways

[Routine Maintenance (Chap.61)]

An example of unit cost preparation for standard maintenance methods of carriageways is given in Table-18. Standardized quantities are preliminarily set for each road condition rank with 3 major work code items: 1) Join and crack filling, 2) Shape correction, and 3) Pothole repair. The same unit costs are applied to maintenance of “Rank-5 (Good)” and “Rank-4 (Fair)” because maintenance scale of these 2 road condition ranks are considered to be equivalent. Unit prices of each work code item are to be determined, referring to the past projects’ information.

Table-19 through Table-21 show the breakdown of standardized repair quantities for each road condition rank that were extracted from actual visual inspection results obtained by DPWT. The extracted repair quantities are multiplied by a factor of 1.5, which is called “Repetitive Factor”, in order to consider repetitive repair works on the same locations. In regard to unit costs for “Rank-5 (Good)” and “Rank-4

(Fair)" that require no or small repair, extra amount of repair quantities are considered for future deterioration and preventive maintenance.

Table-18 An Example of Unit Costs of Standard Routine Maintenance Method (Chap.61)

Rank-1 (Bad):

- Method-2 (Routine Maintenance): Repair (very severe)

Code	Maintenance Work	Unit	Price ($)	Quantity	Cost ($/5km)		
1131	Join and Crack Filling	m2	3.63	2,617.5	9,501.53		
1150	Shape Correction	m2	8.17	3,019.5	24,669.32		
1100	Pothole Repair by AC	m2	11.68	0.0	0.00		Unit cost
				($/5km)	34,170.84	($/km)	6,834.17

Rank-2 (Very poor):

- Method-1 (Routine Maintenance): Repair (severe)

Code	Maintenance Work	Unit	Price ($)	Quantity	Cost ($/5km)		
1131	Join and Crack Filling	m2	3.63	1,522.5	5,526.68		
1150	Shape Correction	m2	8.17	2,300.3	18,793.04		
1100	Pothole Repair by AC	m2	11.68	123.0	1,436.64		Unit cost
				($/5km)	25,756.36	($/km)	5,151.27

Rank-3 (Poor):

- Method-1 (Routine Maintenance): Repair (moderate)

Code	Maintenance Work	Unit	Price ($)	Quantity	Cost ($/5km)		
1131	Join and Crack Filling	m2	3.63	1,496.3	5,431.39		
1150	Shape Correction	m2	8.17	1,317.3	10,762.34		
1100	Pothole Repair by AC	m2	11.68	123.0	1,436.64		Unit cost
				($/5km)	17,630.37	($/km)	3,526.07

Rank-4 (Fair): Repair (small) and preventive maintenance

Code	Maintenance Work	Unit	Price ($)	Quantity	Cost ($/5km)		
1131	Join and Crack Filling	m2	3.63	699.8	2,540.09		
1150	Shape Correction	m2	8.17	543.0	4,436.31		
1100	Pothole Repair by AC	m2	11.68	0.0	0.00		Unit cost
				($/5km)	6,976.40	($/km)	1,395.28

Rank-5 (Good): Preventive maintenance

Code	Maintenance Work	Unit	Price ($)	Quantity	Cost ($/5km)		
1131	Join and Crack Filling	m2	3.63	699.8	2,540.09		
1150	Shape Correction	m2	8.17	543.0	4,436.31		
1100	Pothole Repair by AC	m2	11.68	0.0	0.00		Unit cost
				($/5km)	6,976.40	($/km)	1,395.28

Unit prices of each work code item are to be determined, referring to the past projects' information.

Standardized quantities are preliminarily set for each road condition rank.

Table-19 The Breakdown of Standardized Repair Quantities for “Rank-1 (Bad)”

Standard repair quantity for "Rank-1 (Bad)"

Source: RN14 (PK20.0-PK25.0)

Ave. IRI: 5.12

Visual: N=3.8 Poor

Code	PK	Length (m)	Width (m)	Area (m2)
1150	22+450	8	16	128
1150	470	15	3.5	52.5
1150	500	20	2.8	56
1150	530	25	30	750
1131	560	40	7	280
1150	600	15	3	45
1150	650	40	7	280
1150	750	30	3.5	105
1150	930	3	3.5	10.5
1150	23+030	35	3	105
1150	130	25	3	75
1150	370	16	3	48
1150	410	7	10	70
1131	460	50	7	350
1131	650	40	7	280
1131	740	50	7	350
1131	800	50	7	350
1131	890	5	4	20
1150	24+700	8	3	24
1131	24+820	20	2	40
1131	24+280	30	2.5	75
1150	900	18	3	54
1150	940	10	7	70
1150	950			0
1150	970	20	7	140
			Total (1131):	1745.0
			Total (1150):	2013.0

Consideration of repetitive repair; factor of 1.5 times 1.5

Standardized quantity (1131):	2617.5
Standardized quantity (1150):	3019.5

Standardized repair quantities for each road condition rank that were extracted from actual visual inspection results obtained by DPWT

The extracted repair quantities are multiplied by a factor of 1.5, which is called “Repetitive Factor”, in order to consider repetitive repair works on the same locations.

Table-20 The Breakdown of Standardized Repair Quantities for “Rank-2 (Very poor)”

Standard repair quantity for "Rank-2 (Very poor)"

Source: RN1 (PK46.5-PK51.5)
Ave. IRI: 3.65
Visual: N=2.2 Poor

Code	PK	Length (m)	Width (m)	Area (m2)
1131	45+550	20	1	20
1131	560	25	0.6	15
1131	750	8	1	8
1131	751	10	0.7	7
1131	770	8	0.5	4
1131	780	25	1	25
1131	820	12	1.5	18
1131	840	10	1	10
1131	880	6	1	6
1131	880	30	1	30
1131	46+900	40	1	40
1150	920	50	1	50
1131	950	30	0.8	24
1131	960	30	1	30
1131	970	30	1	30
1150	970	30	1	30
1150	47+00	40	2	80
1150	50	50	1	50
1150	60	30	2	60
1150	100	30	1	30
1150	100	100	1.5	150
1150	160	10	1	10
1150	160	50	2	100
1150	260	50	1	50
1150	340	30	1	30
1150	340	30	3	90
1150	400	80	1	80
1150	550	3	1	3
1150	620	3	1	3
1131	47+760	10	0.6	6
1150	800	20	2	40
1131	880	11	1	11
1131	890	10	1	10
1131	890	10	1	10
1131	960	3	1	3
1131	47+960	10	0.6	6

Code	PK	Length (m)	Width (m)	Area (m2)
1131	48+00	30	0.7	21
1131	100	12	1	12
1131	130	100	1	100
1131	170	40	0.5	20
1131	240	40	1	40
1131	450	50	1	50
1131	500	100	1	100
1131	660	5	1	5
1131	680	30	1	30
1150	740	40	2	80
1150	860	15	1	15
1150	880	25	1	25
1150	48+900	10	1	10
1150	910	20	1	20
1150	950	50	2	100
1150	970	10	1	10
1150	970	4	1	4
1150	990	4	1	4
1150	49+010	4	1	4
1150	50	100	1	100
1131	49+550	50	1	50
1150	670	50	2	100
1150	780	60	1.5	90
1150	900	30	1	30
1150	910	40	0.5	20
1150	980	20	1.5	30
1131	970	30	0.8	24
1131	50+000	25	1	25
1131	50+110	40	1	40
1131	190	50	1	50
1131	300	50	1	50
1150	50+400	10	1	10
1131	450	30	1	30
1131	500	50	0.6	30
1131	550	25	1	25
1150	850	17	1.5	25.5

Total (1131): 1015.0
Total (1150): 1533.5

Consideration of repetitive repair; factor of 1.5

Standardized quantity (1131): 1522.5
Standardized quantity (1150): 2300.3

Source: RN1 (PK16.3-PK21.3)
Ave. IRI: 2.19
Visual: N=3.0 Poor

Code	PK	Length (m)	Width (m)	Area (m2)
1161	16+380	2	1	2.0
1161	440	40	0.5	20.0
1161	442	50	0.5	25.0
1161	590	20	0.5	10.0
1161	600	20	1	20.0
1161	18+630	5	1	5.0

Total: 82.0

Consideration of repetitive repair; factor of 1.5

Standardized quantity : 123.0

Table-21 The Breakdown of Standardized Repair Quantities for “Poor” and “Fair”

Standard repair quantity for "Rank-3 (Poor)"

Source: RN1 (PK54.5-PK59.5)
Ave. IRI: 2.52
Visual: N=2.2 Poor

Code	PK	Length (m)	Width (m)	Area (m2)
1131	490	30	0.8	24
1131	54+530	11	0.5	5.5
1150	660	50	0.8	40
1131	55+100	30	0.5	15
1131	380	10	0.6	6
1131	450	8	1	8
1131	480	15	1	15
1131	530	60	1	60
1131	800	20	1	20
1150	56+160	30	1.5	45
1150	210	40	0.8	32
1150	220	10	1	10
1150	300	30	1	30
1150	350	50	1.5	75
1150	480	20	1.5	30
1150	500	50	2	100
1150	640	12	1	12
1150	640	20	1	20
1150	670	18	1.5	27
1150	690	12	2.5	30
1150	56+850	50	1	50
1150	920	40	1.5	60
1150	960	10	1	10
1150	970	30	1.5	45
1150	57+00	30	2	60
1150	600	70	2	140
1150	800			0
1131	900	15	0.6	9
1150	58+020	40	1	40
1150	150	12	0.6	7.2
1150	700	8	1	8
1150	800	7	1	7
1131	900	100	4	400
1131	59+00	180	2	360
1131	180	40	0.5	20
1131	230	10	0.5	5
1131	350	50	1	50

Total (1131): 997.5
Total (1150): 878.2

Consideration of repetitive repair; factor of 1.5

Standardized quantity (1131): 1496.3
Standardized quantity (1150): 1317.3

Standard repair quantity for "Rank-4 (Fair)"

Source: RN1 (PK51.5-PK56.5)
Ave. IRI: 3.13
Visual: N=1.2 Poor

Code	PK	Length (m)	Width (m)	Area (m2)
1131	51+680	20	0.6	12
1131	51+980	20	0.6	12
1131	52+030	20	0.8	16
1131	320	10	1	10
1131	390	20	1	20
1131	490	40	1	40
1131	53+250	50	0.6	30
1131	350	10	1	10
1131	540	46	3	138
1131	54+180	10	1	10
1131	190	30	0.5	15
1131	490	30	0.8	24
1131	54+530	11	0.5	5.5
1150	660	50	0.8	40
1131	55+100	30	0.5	15
1131	380	10	0.6	6
1131	450	8	1	8
1131	480	15	1	15
1131	530	60	1	60
1131	800	20	1	20
1150	56+160	30	1.5	45
1150	210	40	0.8	32
1150	220	10	1	10
1150	300	30	1	30
1150	350	50	1.5	75
1150	480	20	1.5	30
1150	500	50	2	100

Total (1131): 466.5
Total (1150): 362.0

Consideration of repetitive repair; factor of 1.5

Standardized quantity (1131): 699.8
Standardized quantity (1150): 543.0

The same unit costs are applied to maintenance of “Rank-5 (Good)” and “Rank-4 (Fair)” because maintenance scale of these 2 road condition ranks are considered to be equivalent.
For these 2 ranks, extra amount of repair quantities are considered for future deterioration and preventive maintenance.

[Periodic Maintenance (Chap.61)]

On the contrary to routine maintenance (Chap.61), repair quantities of maintenance methods under periodic maintenance (Chap.61) are not standardized. As shown in Table-22, the quantities are to be determined based on analysis on inspection results. Unit prices of each work code item are to be determined, referring to the past projects' information as well as those for routine maintenance.

Table-22 An Example of Unit Cost of Standard Periodic Maintenance Method (Chap.61)

- Method-2 (Periodic Maintenance): Resurfacing/ Overlay

Maintenance Work	Overlay area (%)	Unit	Price ($)	Quantity	Cost ($/5km)		
Overlay with AC	100	m2	10.00	35,000.0	350,000.00		Unit cost
				($/5km)	350,000.00	($/km)	70,000.00

Enter overlay area ratio (%)

Unit prices of each work code item are to be determined, referring to the past projects' information.

Quantities are to be set based on "overlay area ratio (%)":
If the overlay area is 100%,
(Quantity)= (width: 7m)*(length: 5000m)*(area: 100%)
= 35000(m2)

(3) Cost Estimation for Maintenance of Carriageways

Maintenance costs for carriageways are to be estimated as follows:

1) Clarify the percentage of each road condition rank according to inspection results.
2) Calculate the distance of each road condition rank: (percentage)*(total road length) = (distance)
3) Determine the unit prices of each work code items: Refer to the past projects' information.
4) Calculate the maintenance costs for each road condition rank: (distance)*(unit cost) = (cost)

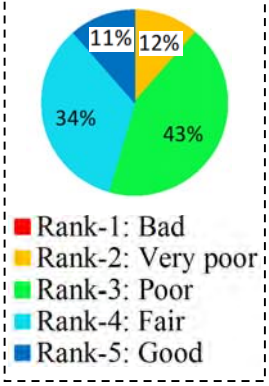
Table-23 illustrates the cost estimation scheme in accordance with the above procedure. Road sections evaluated as "Rank-1 (Bad)" have the 3 optional maintenance methods: Method-1 (Investment: reconstruction), Method-2 (Routine maintenance: repair), and Method-3 (Periodic maintenance: overlay). In the case where Method-1 (Investment: reconstruction) is selected, the road sections are to be excluded from the maintenance plans under Chap.61 and taken over in maintenance plans under Chap.21. Also, Road sections evaluated as "Rank-2 (Very poor)" and "Rank-3 (Poor)" have the 2 optional maintenance methods: Method-1 (Routine maintenance: repair), and Method-2 (Periodic maintenance: overlay). For, road sections evaluated as "Rank-4 (Fair)" and "Rank-5 (Good)", routine maintenance (repair) is automatically applied.

The cost estimate format shown in Table-23 is to be converted into the budget request format shown in Figure-17.

Table-23 Cost Estimate for Maintenance of Carriageways under Chap.61

Road Condtion		Percentage (%)	Distance (km)	Unit Cost ($/km)	Cost ($)	Maintenance Category	
Rank-1: Bad	Method-1	**0.0**	**0.0**	-	-	Chap.21	Investment (Excluded)
	Method-2	**0.0**	0.0	6,834.17	0.00	Chap.61	Routine Maintenance
	Method-3	**0.0**	0.0	70,000.00	0.00		Periodic Maintenance
Rank-2: Very poor	Method-1	**11.4**	5.0	5,151.27	25,756.36	Chap.61	Routine Maintenance
	Method-2	**0.0**	0.0	70,000.00	0.00		Periodic Maintenance
Rank-3: Poor	Method-1	**43.4**	19.1	3,526.07	67,348.01	Chap.61	Routine Maintenance
	Method-2	**0.0**	0.0	70,000.00	0.00		Periodic Maintenance
Rank-4: Fair		**34.1**	15.0	1,395.28	20,929.21	Chap.61	Routine Maintenance
Rank-5: Good		**11.1**	4.9	1,395.28	6,836.87		
Total:		100	44.0		**120,870.45**	(Chap.61)	

(Distance)*(Unit cost) = (Cost)



Rank-2 (Very poor):

- Method-1 (Routine Maintenance): Repair (severe)

Code	Maintenance Work	Unit	Price ($)	Quantity	Cost ($/5km)
1131	Join and Crack Filling	m2	3.63	1,522.5	5,526.68
1150	Shape Correction	m2	8.17	2,300.3	18,793.04
1100	Pothole Repair by AC	m2	11.68	123.0	1,436.64
				($/5km)	25,756.36
				($/km)	5,151.27

Rank-3 (Poor):

- Method-1 (Routine Maintenance): Repair (moderate)

Code	Maintenance Work	Unit	Price ($)	Quantity	Cost ($/5km)
1131	Join and Crack Filling	m2	3.63	1,496.3	5,431.39
1150	Shape Correction	m2	8.17	1,317.3	10,762.34
1100	Pothole Repair by AC	m2	11.68	123.0	1,436.64
				($/5km)	17,630.37
				($/km)	3,526.07

Rank-4 (Fair): Repair (small) and preventive maintenance

Code	Maintenance Work	Unit	Price ($)	Quantity	Cost ($/5km)
1131	Join and Crack Filling	m2	3.63	699.8	2,540.09
1150	Shape Correction	m2	8.17	543.0	4,436.31
1100	Pothole Repair by AC	m2	11.68	0.0	0.00
				($/5km)	6,976.40
				($/km)	1,395.28

Rank-5 (Good): Preventive maintenance

Code	Maintenance Work	Unit	Price ($)	Quantity	Cost ($/5km)
1131	Join and Crack Filling	m2	3.63	699.8	2,540.09
1150	Shape Correction	m2	8.17	543.0	4,436.31
1100	Pothole Repair by AC	m2	11.68	0.0	0.00
				($/5km)	6,976.40
				($/km)	1,395.28

Road Condtion		Percentage (%)	Distance (km)	Unit Cost ($/km)	Cost ($)	Maintenance Category	
Rank-1: Bad	Method-1	**0.0**	**0.0**	-	-	Chap.21	Investment (Excluded)
	Method-2	**0.0**	0.0	6,834.17	0.00	Chap.61	Routine Maintenance
	Method-3	**0.0**	0.0	70,000.00	0.00		Periodic Maintenance
Rank-2: Very poor	Method-1	**11.4**	5.0	5,151.27	25,756.36	Chap.61	Routine Maintenance
	Method-2	**0.0**	0.0	70,000.00	0.00		Periodic Maintenance
Rank-3: Poor	Method-1	**43.4**	19.1	3,526.07	67,348.01	Chap.61	Routine Maintenance
	Method-2	**0.0**	0.0	70,000.00	0.00		Periodic Maintenance
Rank-4: Fair		**34.1**	15.0	1,395.28	20,929.21	Chap.61	Routine Maintenance
Rank-5: Good		**11.1**	4.9	1,395.28	6,836.87		
Total:		100	44.0		**120,870.45**	(Chap.61)	

To be converted into the budget request format

Code	Maintenance Work	Unit	Quantity	Price ($)	Cost ($)
1131	Join and Crack Filling	m2	10,023.18	3.63	36,384.14
1150	Shape Correction	m2	9,493.48	8.17	77,561.70
1100	Pothole Repair by AC	m2	592.86	11.68	6,924.60
-	Overlay with AC	m2	0.00	10.00	0.00
				Total: ($)	120,870.45

Figure-17 Conversion of Cost Estimate Format

5.3 Cost Estimation System for Carriageways of Unpaved Roads

5.3.1 Selection of Maintenance Methods

Maintenance methods for unpaved roads are selected according to IRI-range criteria shown in Table-24. Road sections with 5km-ave. IRI values under 5.0 are preventively maintained by 1) heavy grading gravel and 2) grading gravel while those with 5km-ave. IRI values equal to/over 5.0 are repaired entirely by heavy grading gravel.

Table-24 Standard Maintenance Methods for Unpaved Roads

IRI (5km-ave.)	Standard Maintenance Methods
IRI<5.0: **No repair**	Preventive maintenance: - Heavy grading gravel road (20% of total carriageway area) - Grading gravel road (80% of total carriageway area)
5.0≤IRI: **Repair**	Repair: - Heavy grading gravel road (100% of total carriageway area)

5.3.2 Cost Estimation Scheme

(1) Unit Costs of Standard Maintenance Methods

An example of unit cost preparation for standard maintenance methods is given in Table-25. Standardized quantities are preliminarily set for each road condition (“Repair” or “No Repair”) using 2 major work code items: 1) Heavy grading gravel road and 2) Grading gravel road. The quantities are determined in keeping with the criteria specified in Table-24. Unit prices of each work code item are to be determined, referring to the past projects’ information.

Table-25 Unit Costs of Standard Maintenance Methods

Unit cost for "Repair"

Code	Maintenance Work	Unit	Unit Price (US$)	Quantity	Cost (US$/5km)
1260	Heavy Grading Gravel Road	m2	0.21	35,000.0	7,465.00
				US$/5km	7,465.00
				Unit cost: US$/km	1,493.00

Unit cost for "Preventive Maintenance"

Code	Maintenance Work	Unit	Unit Price (US$)	Quantity	Cost (US$/5km)
1260	Heavy Grading Gravel Road	m2	0.21	7,000.0	1,493.00
1250	Grading Gravel Road	m2	0.11	28,000.0	2,986.00
				US$/5km	4,479.00
				Unit cost: US$/km	895.80

To be determined, based on past projects' information

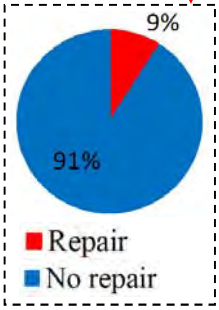
Standardized quantities

(2) Cost Estimation for Maintenance of Carriageways

Maintenance costs for carriageways are to be estimated by the same procedure for paved roads as illustrated in Figure-18.

Road Condition	Percentage (%)	Distance (km)	Unit Cost (US$/km)	Cost (US$)	Remarks
Repair	9	1.0	1,493.00	1,465.85	To be repaired
No repair	91	9.8	895.80	8,795.13	Preventive maintenance
Total:	100	10.8		10,260.98	(Chap.61)

(Distance)*(Unit cost) =(Cost)



Unit cost for "Repair"

Code	Maintenance Work	Unit	Unit Price (US$)	Quantity	Cost (US$/5km)
1260	Heavy Grading Gravel Road	m2	0.21	35,000.0	7,465.00
				US$/5km	7,465.00
				Unit cost: US$/km	1,493.00

Unit cost for "Preventive Maintenance"

Code	Maintenance Work	Unit	Unit Price (US$)	Quantity	Cost (US$/5km)
1260	Heavy Grading Gravel Road	m2	0.21	7,000.0	1,493.00
1250	Grading Gravel Road	m2	0.11	28,000.0	2,986.00
				US$/5km	4,479.00
				Unit cost: US$/km	895.80

Converted into the budget request format

Code	Maintenance Work	Unit	Unit Price (US$)	Quantity	Cost (US$)
1250	Grading Gravel Road	m2	0.21	20,618.18	4,397.56
1260	Heavy Grading Gravel Road	m2	0.11	54,981.82	5,863.42
				Total: US$	10,260.98
				US$/km	950.09

Figure-18 Cost Estimate for Maintenance of Carriageways

5.4 Cost Estimation System for Off-carriageway/ Structures/ Road Furniture

Maintenance costs for 1) off-carriageway, 2) structures, and 3) road furniture shall be estimated, complying with standard maintenance methods specified in Table-26. The standard maintenance methods and specifications have been defined digit-class by digit-class, referring to the past projects' information.

Table-26 Standard Maintenance Methods for Off-carriageway/ Structures/ Road Furniture

1-digit roads

Category	Code	Work Type	Unit	Specifications for Cost Estimate
Off-carriage way	1200	Grading shoulders	km	20% of road length
	1201-2	Adding gravel	m3	10% of road length (2sides*0.5m wide*0.5m deep)
	2100	Cleaning channels by labor	m	10% of road length
	2110	Cleaning channels by machine	m	100% of road length
	4150	Vegetation control (shrub, plant and tree)	km	Road length
Structures	3100	Cleaning culvert (transversal)	place	1.5place/km
	3110	Cleaning culvert (longitudinal)	m	3% of road length
	3200	Minor bridge repair (cleaning, painting)	man/h	5(man/h)/km
Road Furniture	5230	Traffic sign repair	pole	0.5pole/km
	6100	Cleaning and painting safety poles	pole	12poles/km
	7100	Cleaning and paiting kilometer posts	pole	1pole/km

2-digit roads

Category	Code	Work Type	Unit	Specifications for Cost Estimate
Off-carriage way	1200	Grading shoulders	km	15% of road length
	1201-2	Adding gravel	m3	8% of road length (2sides*0.5m wide*0.5m depth)
	2100	Cleaning channels by labor	m	10% of road length
	2110	Cleaning channels by machine	m	10% of road length
	4150	Vegetation control (shrub, plant and tree)	km	100% of road length
Structures	3100	Cleaning culvert (transversal)	place	1.5place/km
	3110	Cleaning culvert (longitudinal)	m	3% of road length
	3200	Minor bridge repair (cleaning, painting)	man/h	5(man/h)/km
Road Furniture	5230	Traffic sign repair	pole	0.5pole/km
	6100	Cleaning and painting safety poles	pole	5poles/km
	7100	Cleaning and paiting kilometer posts	pole	1pole/km

3&4-digit roads

Category	Code	Work Type	Unit	Specifications for Cost Estimate
Off-carriage way	1200	Grading shoulders	km	15% of road length
	1201-2	Adding gravel	m3	5% of road length (2sides*0.5m wide*0.5m depth)
	2100	Cleaning channels by labor	m	5% of road length
	2110	Cleaning channels by machine	m	5% of road length
	4150	Vegetation control (shrub, plant and tree)	km	70% of road length
Structures	3100	Cleaning culvert (transversal)	place	1.5place/km
	3200	Minor bridge repair (cleaning, painting)	man/h	2(psn./hr)/km
Road Furniture	5230	Traffic sign repair	pole	0.5pole/km
	6100	Cleaning and painting safety poles	pole	5poles/km
	7100	Cleaning and paiting kilometer posts	pole	1pole/km

Standardized unit costs of the 3 maintenance categories are summarized in Table-27. The quantities are set according to the specifications shown in Table-26. Also, unit prices of work code items are set based on past projects' information.

Table-27 Unit Costs for Off-carriageway/ Structures/ Road Furniture

1-digit roads Road length (km): 100

Category	Code	Work Type	Unit	Quanity	Unit Price (US$/unit)	Cost (US$ per 100km)	Unit Cost (US$/km)
Off-carriage way	1200	Grading shoulders	km	20.0	365.90	7,318.08	700.00
	1201-2	Adding gravel	m3	5,000	7.75	38,758.50	
	2100	Cleaning channels by labor	m	10,000	0.46	4,633.65	
	2110	Cleaning channels by machine	m	10,000	1.23	12,315.48	
	4150	Vegetation control (shrub, plant and tree)	km	100.0	70.05	7,004.85	
Structures	3100	Cleaning culvert (transversal)	place	150	24.65	3,697.26	108.00
	3110	Cleaning culvert (longitudinal)	m	3,000	1.37	4,123.63	
	3200	Minor bridge repair (cleaning, painting)	man/h	500	6.10	3,050.18	
Road Furniture	5230	Traffic sign repair	pole	50	130.68	6,533.84	236.00
	6100	Cleaning and painting safety poles	pole	1,200	11.80	14,161.76	
	7100	Cleaning and paiting kilometer posts	pole	100	29.11	2,910.65	
					Total:	104,507.86 (US$)	1,044.00 (US$/km)

2-digit roads Road length (km): 100

Category	Code	Work Type	Unit	Quanity	Unit Price (US$/unit)	Cost (US$ per 100km)	Unit Cost (US$/km)
Off-carriage way	1200	Grading shoulders	km	15.0	365.90	5,488.56	604.00
	1201-2	Adding gravel	m3	4,000	7.75	31,006.80	
	2100	Cleaning channels by labor	m	10,000	0.46	4,633.65	
	2110	Cleaning channels by machine	m	10,000	1.23	12,315.48	
	4150	Vegetation control (shrub, plant and tree)	km	100.0	70.05	7,004.85	
Structures	3100	Cleaning culvert (transversal)	place	150	24.65	3,697.26	108.00
	3110	Cleaning culvert (longitudinal)	m	3,000	1.37	4,123.63	
	3200	Minor bridge repair (cleaning, painting)	man/h	500	6.10	3,050.18	
Road Furniture	5230	Traffic sign repair	pole	50	130.68	6,533.84	153.00
	6100	Cleaning and painting safety poles	pole	500	11.80	5,900.73	
	7100	Cleaning and paiting kilometer posts	pole	100	29.11	2,910.65	
					Total:	86,665.62 (US$)	865.00 (US$/km)

3&4-digit roads Road length (km): 100

Category	Code	Work Type	Unit	Quanity	Unit Price (US$/unit)	Cost (US$ per 100km)	Unit Cost (US$/km)
Off-carriage way	1200	Grading shoulders	km	15.0	365.90	5,488.56	382.00
	1201-2	Adding gravel	m3	2,500	7.75	19,379.25	
	2100	Cleaning channels by labor	m	5,000	0.46	2,316.83	
	2110	Cleaning channels by machine	m	5,000	1.23	6,157.74	
	4150	Vegetation control (shrub, plant and tree)	km	70.0	70.05	4,903.40	
Structures	3100	Cleaning culvert (transversal)	place	150	24.65	3,697.26	49.00
	3200	Minor bridge repair (cleaning, painting)	man/h	200	6.10	1,220.07	
Road Furniture	5230	Traffic sign repair	pole	50	130.68	6,533.84	153.00
	6100	Cleaning and painting safety poles	pole	500	11.80	5,900.73	
	7100	Cleaning and paiting kilometer posts	pole	100	29.11	2,910.65	
					Total:	58,508.32 (US$)	584.00 (US$/km)

5.5 Preparation of Budget Request Forms

Budget request forms are to be prepared as follows.

1) Road Information

(1)	Road Name	RN1 (Kandal)
(2)	Road Length (km)	44.0
(3)	Pavement Type	AC
(4)	The number of Lanes	2
(5)	Carriageway width (m)	7.0
(6)	Road Class	1-digit roads

Note: - Standard carriageway width is 7.0m (2 lanes).
- "Carriageway width" is set by 2 lanes even if it has 4 lanes.

2) Maintenance Cost for Carriageways

Code	Maintenance Work	Unit	Quantity	Price ($)	Cost ($)	
1131	Join and Crack Filling	m2	10,023.18	3.63	36,384.14	
1150	Shape Correction	m2	9,493.48	8.17	77,561.70	
1100	Pothole Repair by AC	m2	592.86	11.68	6,924.60	
-	Overlay with AC	m2	0.00	10.00	0.00	Unit cost
				Total:	120,870.45	2,747
					($)	($/km)

3) Maintenance Cost for Off-carriageway/ Structures/ Road Furniture (for 1-digit roads)

Category	Code	Work Type	Unit	Quanity	Unit Price ($/unit)	Cost ($ per 44km)	Unit Cost ($/km)
Off-carriage way	1200	Grading shoulders	km	8.8	365.9	3,219.96	700.00
	1201-2	Adding gravel	m3	2,200	7.8	17,053.74	
	2100	Cleaning channels by labor	m	4,400	0.5	2,038.81	
	2110	Cleaning channels by machine	m	4,400	1.2	5,418.81	
	4150	Vegetation control (shrub, plant and tree)	km	44.0	70.0	3,082.13	
Structures	3100	Cleaning culvert (transversal)	place	66.0	24.6	1,626.80	108.00
	3110	Cleaning culvert (longitudinal)	m	1,320	1.4	1,814.40	
	3200	Minor bridge repair (cleaning, painting)	man/h	220.0	6.1	1,342.08	
Road Furniture	5230	Traffic sign repair	pole	22.0	130.7	2,874.89	236.00
	6100	Cleaning and painting safety poles	pole	528.0	11.8	6,231.17	
	7100	Cleaning and paiting kilometer posts	pole	44.0	29.1	1,280.69	
					Total:	45,983.46	1,044.00

4) Budget Request Forms

Code	Work Type	Unit	Quanity	Unit Price ($/unit)	Cost ($)
1131	Join and Crack Filling	m2	10,023.18	3.63	36,384.14
1150	Shape Correction	m2	9,493.48	8.17	77,561.70
1100	Pothole Repair by AC	m2	592.86	11.68	6,924.60
-	Overlay with AC		0.00	10.00	0.00
1200	Grading shoulders	km	8.80	365.90	3,219.96
1201-2	Adding gravel	m3	2,200.00	7.75	17,053.74
2100	Cleaning channels by labor	m	4,400.00	0.46	2,038.81
2110	Cleaning channels by machine	m	4,400.00	1.23	5,418.81
4150	Vegetation control (shrub, plant and tree)	km	44.00	70.05	3,082.13
3100	Cleaning culvert (transversal)	place	66.00	24.65	1,626.80
3110	Cleaning culvert (longitudinal)	m	1,320.00	1.37	1,814.40
3200	Minor bridge repair (cleaning, painting)	man/h	220.00	6.10	1,342.08
5230	Traffic sign repair	pole	22.00	130.68	2,874.89
6100	Cleaning and painting safety poles	pole	528.00	11.80	6,231.17
7100	Cleaning and paiting kilometer posts	pole	44.00	29.11	1,280.69
				Toatal: ($)	166,853.91

CHAPTER 6 Step.5: Budget Request for Road Maintenance Plans & Step.6: Implementation of Road Maintenance Plans

6.1 Step.5: Budget Request for Road Maintenance Plans

In Step.5, budget request shall be made to Ministry of Economy and Finance (MEF) with approximate inspection/maintenance plans with costs in order to get approval for the implementation. The budget request procedure is explained in the annual action plan shown in Figure-19.

First of all, approximate maintenance plans with costs are cooperatively prepared by MPWT and DPWT. Then, target roads for inspection and maintenance planning are selected. After that, MPWT prepares budget request forms for the selected plans and negotiate with MEF in order to get approval for the plans and budget allocation. After the approval, MPWT finalizes the plans and determine the maintenance costs through discussion with MEF. Finally, notice to proceed is given to DPWTs and the plans are implemented after scheduling the projects.

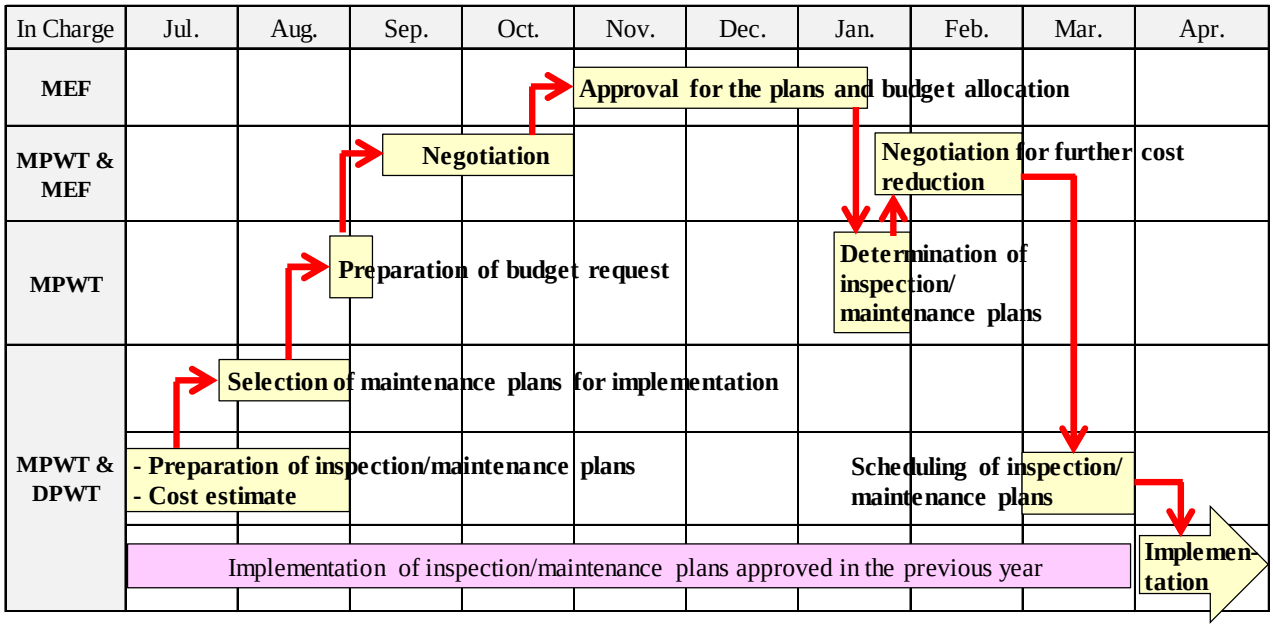


Figure-19 The Annual Action Plan for Road Maintenance

6.2 Step.6: Implementation of Road Maintenance Plans

Approved maintenance plans are to be implemented in Step.6. The following 2 guidelines shall be referred to for instructions.

1) Guidelines for Supervision of Routine Maintenance
2) Guidelines for Repairing Defects of Road

CHAPTER 7 Feedback of Road Maintenance Works

7.1 Feedback of Road Maintenance Works

After completion of maintenance works, the effectiveness of the works shall be reviewed in "Feedback" stage. The first thing to be done in the feedback stage is conduct of IRI measurement with visual inspection again. Then, as illustrated in Figure-20, road conditions of before and after maintenance works shall be compared with the following two (2) indicators;

1) IRI
2) Indicator-N

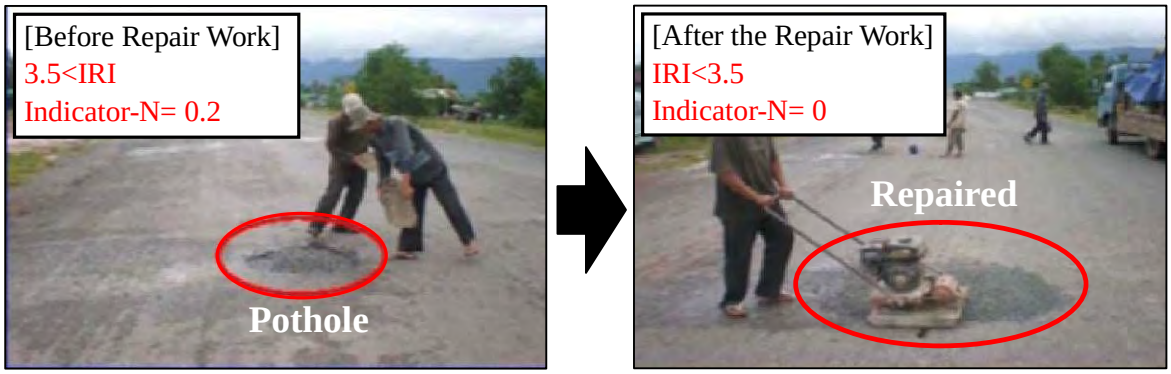


Figure-20 Comparison of IRI Values between before and after Maintenance Works

The feedback results shall be appropriately summarized as described below.

7.2 Feedback Schemes

(1) Preparation of IRI Measurement Record

Average IRI values (total road section) of inspected roads should be recorded at least annually for important roads such as 1-digit roads in order to examine change of road conditions over the years. An example of IRI measurement record is shown in Figure-21. The preparation of the record enables us to identify weak points of the road network.

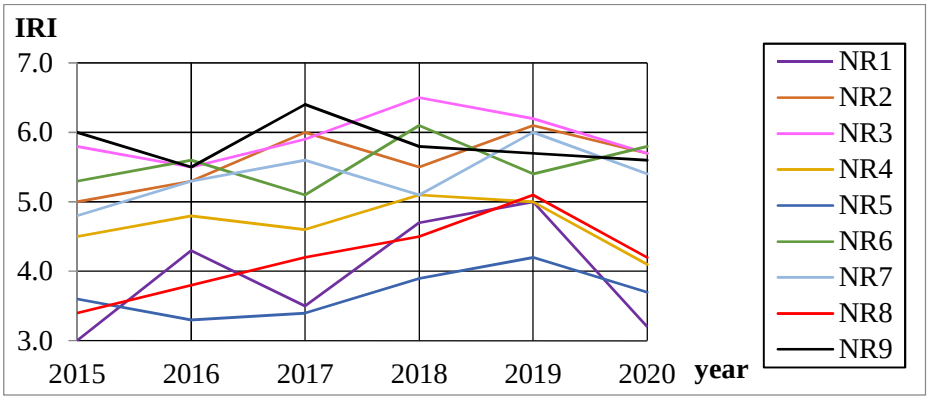


Figure-21 The Record of Average IRI Values

(2) Preparation of Visual Inspection Record

In addition to the IRI measurement record, visual inspection record can be applied to important roads such as 1-digit roads. The record could cover identification of weak points overlooked in IRI measurement. An example of the visual inspection record is shown in Figure-22.

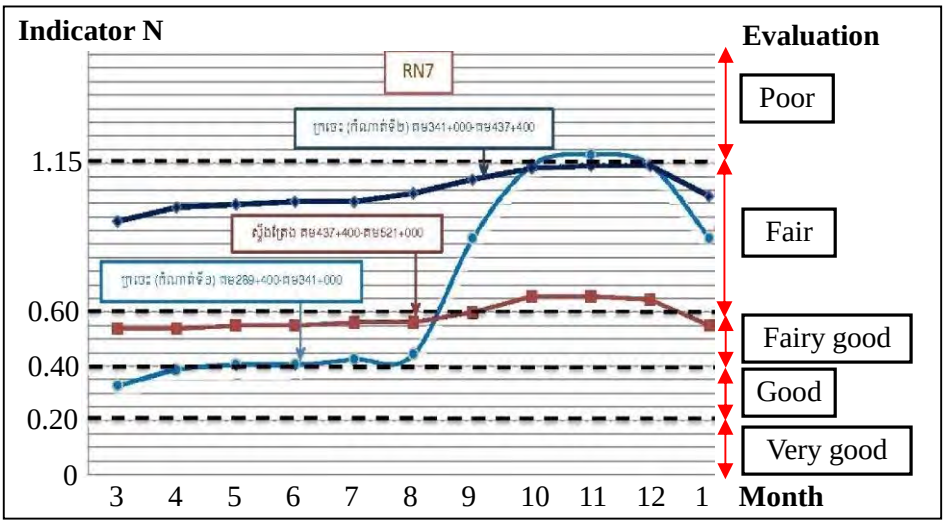


Figure-22 Record of Visual Inspection Results

(3) Preparation of Road Hazard Maps

It is desirable that road hazard maps should be established, based on the identified weak points in the entire road network of Cambodia. The above two (2) records will be basic information to identify vulnerable road sections. The hazard maps could be beneficial to both planning and maintenance of the road network system. For preparation of the hazard maps, accumulation of inspection results is essential.

CHAPTER 8 An Example of the Guidelines Application

8.1 Outline

This Chapter gives an example of the way to practically apply the guidelines to actual routine road maintenance planning and cost estimate, based on an actual IRI measurement and visual inspection result. The example explains Step.1 through Step.4 of the routine road maintenance system using IRI.

8.2 Inspection Conditions

The inspection has been conducted under the following conditions.

- Inspection course: Partial sections of Road Number 1 (RN1; PK3.5km (start)–PK53.4km (end), 49.9km)
- Equipment for IRI measurement: Dynamic Response Intelligent Monitoring System (DRIMS)
- Members of the inspection team: One (1) driver and One (1) inspector (in charge of both IRI measurement and visual inspection)

8.3 Step.1: IRI Measurement and Visual Inspection

8.3.1 IRI Measurement

Figure-23 shows a result of IRI measurement, called “IRI map” of the inspected road. As it can be confirmed in the graph over the map, average IRI values range from 1.6 to 10.0 (calculation interval: 10m). Entirely, the road conditions are quite good while partially deteriorated road sections are identified. In this way, preparation of IRI maps enables us to see the entire road conditions easily and visually. Further analysis on the inspection result is to be given in Step.2.

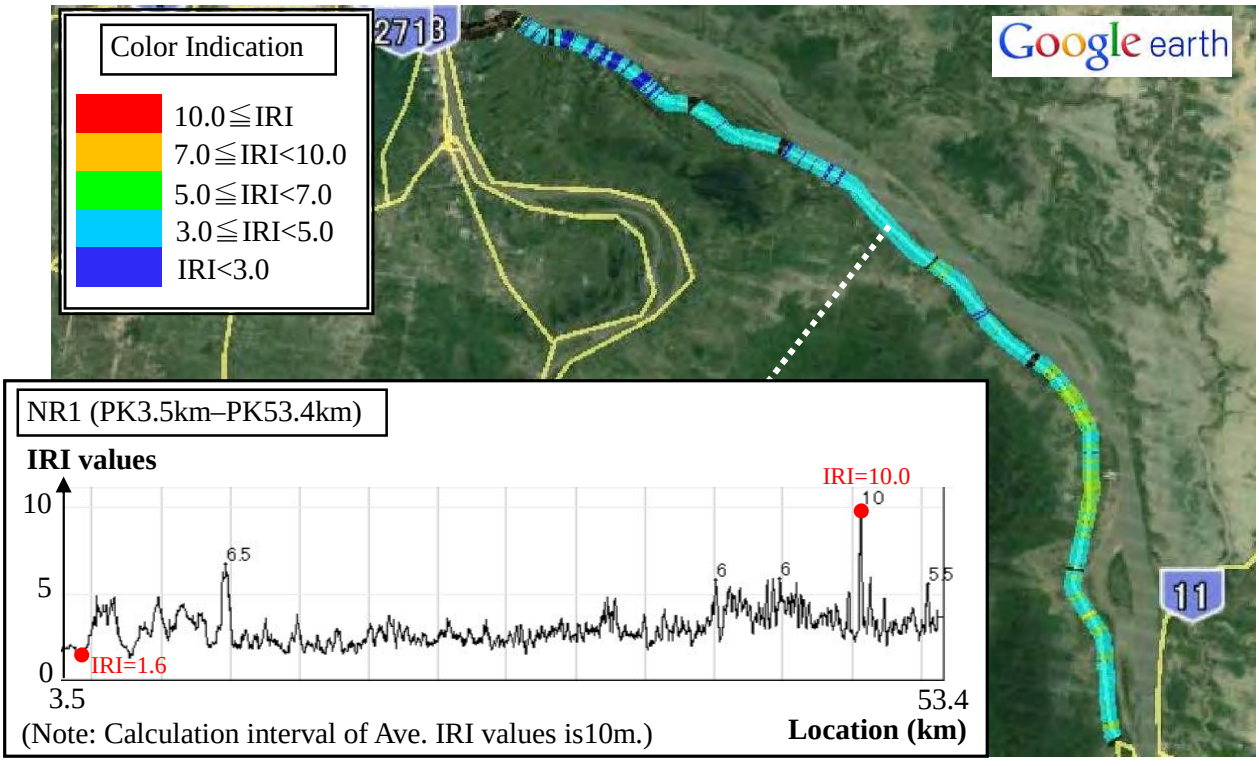


Figure-23 An IRI Map of the Inspected Road (NR1)

8.3.2 Visual Inspection

Characteristics of the road sections were identified through visual inspection. Major findings are:

- Confirmation of ongoing road construction work around 0-0.4km section,
- Deterioration of road surface around 0-0.4km section,
- Bumps due to projected lane marks around 31-32km section,
- Bumps due to rough road surface around 33-43km section,
- Bumps due to insufficient bridge expansion joints around 47.5km section, and
- Bumps due to deformation of road surface around 48km point.

Note: Start point is set as “0km”.

Some of the major findings are visually summarized in Figure-24.

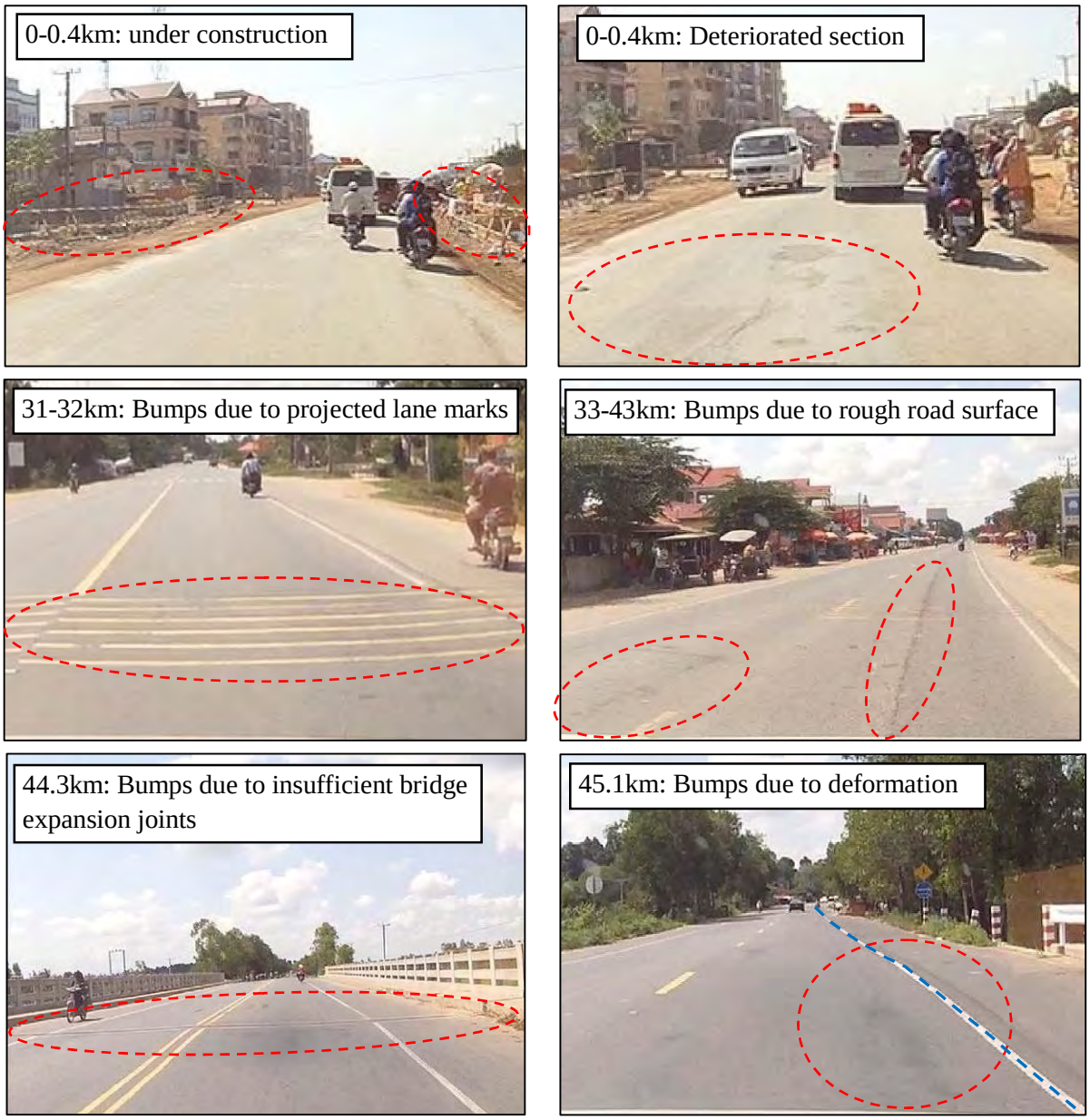


Figure-24 Major Findings of Visual Inspections

The major findings like the above can be reported in “(14) Remarks” of the inventory after the inspection as shown in Figure-26

8.4 Step.2: Evaluation of Inspection Results

8.4.1 Preparation of Road Inventory and Inspection Review Sheet

Results of IRI measurement and visual inspection obtained in Step.1 are summarized in the Road Inventory shown in Figure-26 through Figure-35 with comments for major points to be considered. Additionally, overall evaluation of the inspection results is outlined in the Inspection Review Sheet shown in Figure-25.

8.4.2 Review on IRI Values

The overall road condition was judged to be in relatively damaged condition by the fact that ave. IRI value of the total road section was 3.0. Large IRI value around 5.0 was confirmed due to rough road surface in several sections. Especially, 5km-ave. IRI values were over 3.5 in Section-7 (30-35km) through Section-9 (40-45km), which indicates the high necessity of repair work. The causes of high IRI values are closely examined in Figure-26 through Figure-35.

8.4.3 Review on Visual Inspection Results

The overall road condition was visually evaluated to be “Poor” with ave. Indicator-N=2.32. Damaged conditions were identified in Section-1 (0-5km), Section-3 (10-15km), Section-6 (25-30km), and Section-8 (35-40km) through Section-10 (45-50km). In particular, the condition of Section-1 (0-5km) was remarkably “Poor” with Indicator-N=10.8.

8.4.4 Overall Evaluation

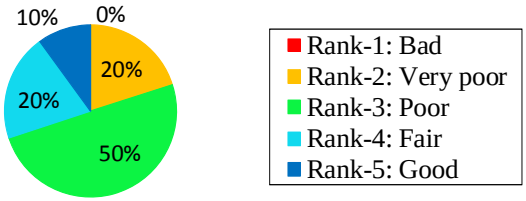
As it is shown in the Pie Chart of Figure-25, 20% of the inspected road sections are in Rank-2 (Very poor) and 50% are in Rank-3 (Poor). Totally, 70% of the inspected road sections need repair work. Section-8 (35-40km) and Section-9 (40-45km) were evaluated as “Rank-2 (Very poor)” as follows and need urgent repair work:

- Section-8 (35-40km): 5km-ave. IRI value of 3.65, Indicator-N of 2.4
- Section-9 (40-45km): 5km-ave. IRI value of 4.12, Indicator-N of 2.0

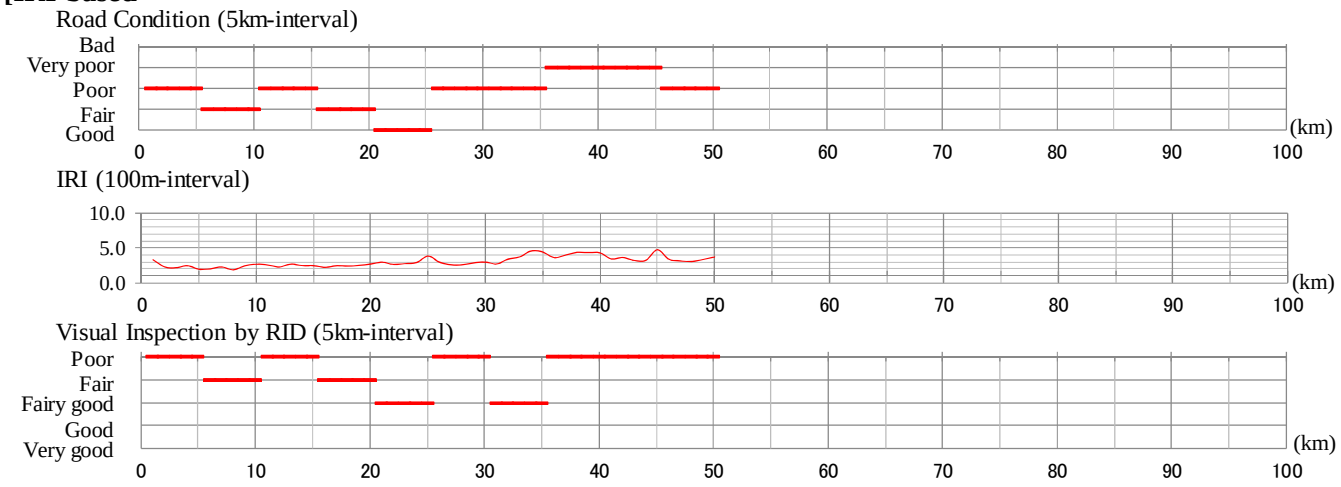
In addition, Section-1 (0-5km), evaluated as “Rank-3 (Poor)” with Indicator-N of 10.8, also need urgent repair although 5km-ave. IRI value of 2.44 is still relatively low.

Inspection Review Sheet (for Paved Roads)

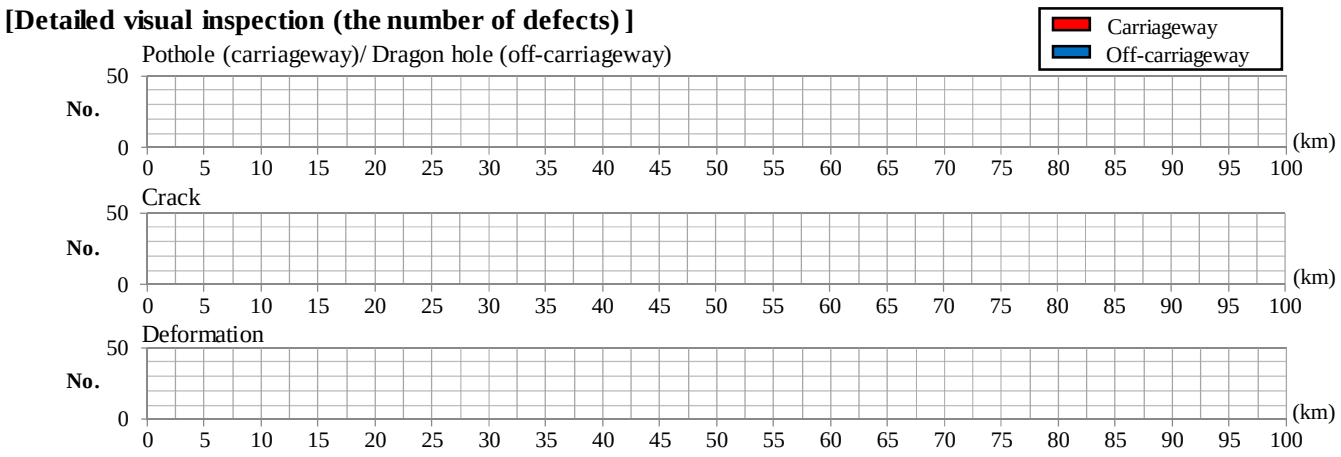
(1)	Road Name	RN1 (Phnom Penh)		Breakdown of Road Condition	
(2)	Road Length (km) (Inspected: 49.9(km))		49.9		
(3)	Pavement Type		AC		
(4)	Date of IRI measurement		24/July/2015		
(5)	Start Point & End Point	Start	PK3+500		
		End	PK53+400		
(6)	Average IRI (Total Section)		3.0		
(7)	Visual Rating (Total Section)	Indicator-N	2.32		
		Evaluation	Poor		
(8)	Repair Ratio (Rank-1+Rank-2+Rank-3)		**69.9%**		
(9)	Urgency Ratio (Rank-1+Rank-2)		**20.0%**	Emergency Ratio (Rank-1)	**0.0%**



[IRI-based



[Detailed visual inspection (the number of defects)]



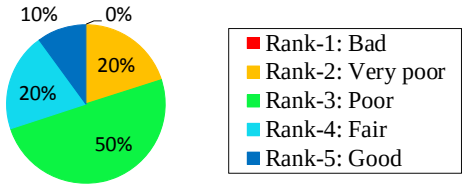
Location				IRI-based inspection					Visual inspection for check					
							Road condition		Carriageway			Off-carriageway		
From		To		Ave. IRI	Visual rating		Rank: Condition	Discription	Pot-hole	Crack	Defor-mation	Defor-mation	Dragon hole	Update
km	PK	km	PK		N	Evaluation								
0	0.0	**5**	5.0	2.44	10.80	Poor	**3:Poor**	Repair (moderate)						
5	5.0	**10**	10.0	2.26	0.80	Fair	**4:Fair**	Repair (small)						
10	10.0	**15**	15.0	2.50	3.20	Poor	**3:Poor**	Repair (moderate)						
15	15.0	**20**	20.0	2.46	0.60	Fair	**4:Fair**	Repair (small)						
20	20.0	**25**	25.0	3.02	0.40	Fairly good	**5:Good**	Regular inspection						
25	25.0	**30**	30.0	2.80	1.40	Poor	**3:Poor**	Repair (moderate)						
30	30.0	**35**	35.0	3.77	0.40	Fairly good	**3:Poor**	Repair (moderate)						
35	35.0	**40**	40.0	4.12	2.40	Poor	**2:Very poor**	Repair/ Resurfacing						
40	40.0	**45**	45.0	3.65	2.00	Poor	**2:Very poor**	Repair/ Resurfacing						
45	45.0	**50**	50.0	3.33	1.20	Poor	**3:Poor**	Repair (moderate)						

Figure-25 Overall Evaluation of the Inspection Result by Inspection Review Sheet

Road Inventory (for Paved Roads)

(1)	Road Name	RN1 (Phnom Penh)				
(2)	Road Length (km)	49.9	Inspected road length:	49.9 km		
(3)	Pavement Type	AC				
(4)	Date of IRI measurement	24/July/2015				
(5)	Start Point & End Point	Start	PK3+500	End	PK53+400	
(6)	Average IRI (Total Section)	3.0				
(7)	Visual Rating (Total Section)	Indicator-N	2.32	Evaluation	Poor	
(8)	Repair Ratio (**Rank-1+Rank-2+Rank-3**)		69.9%			
(9)	Urgency Ratio (**Rank-1+Rank-2**)	20.0%	Emergency Ratio (**Rank-1**)	0.0%		

Breakdown of the Road Condition



(10) Location		(11) Average IRI			(12) Visual Rating (Per 5.0km)				(13) Road Condition (Per 5.0km)	(14) Remarks	
From	To	Per 100m	Per 1.0km	Per 5.0km	No.of Defects Per 100m	No.of Defects Per 5.0km	N	Evaluation		No. of Bridge Joints	Major Findings
0 km + 0	0 km + 100	3.1			1					0	0-0.4km: under construction
0 km + 100	0 km + 200	5.8			0					0	0-0.4km: deteriorated section
0 km + 200	0 km + 300	6.2			1					0	
0 km + 300	0 km + 400	4.8			1					0	0.2km: large deformation
0 km + 400	0 km + 500	2.7			3					0	
0 km + 500	0 km + 600	2.0	3.3	-	0	-	-	-	-	0	
0 km + 600	0 km + 700	2.0			3						
0 km + 700	0 km + 800	2.0			4						
0 km + 800	0 km + 900	2.2			1						
0 km + 900	1 km + 0	2.4			2					0	
1 km + 0	1 km + 100	2.7			2					0	
1 km + 100	1 km + 200	2.8			2					0	
1 km + 200	1 km + 300	2.2			3					0	
1 km + 300	1 km + 400	2.0			1					0	
1 km + 400	1 km + 500	2.2			0					0	
1 km + 500	1 km + 600	2.5	2.3	-	1	-	-	-	-	0	
1 km + 600	1 km + 700	2.3			6						
1 km + 700	1 km + 800	2.1			1						
1 km + 800	1 km + 900	2.0			0						
1 km + 900	2 km + 0	2.2			0						
2 km + 0	2 km + 100	3.0			1						
2 km + 100	2 km + 200	2.7			1						
2 km + 200	2 km + 300	2.4			1						
2 km + 300	2 km + 400	2.3			0					0	
2 km + 400	2 km + 500	2.2			0					0	
2 km + 500	2 km + 600	2.1	2.2	-	0	-	-	-	-	0	
2 km + 600	2 km + 700	2.0			5					0	
2 km + 700	2 km + 800	1.9			3					0	
2 km + 800	2 km + 900	1.7			1					0	
2 km + 900	3 km + 0	1.6			2					0	
3 km + 0	3 km + 100	1.7			0					0	
3 km + 100	3 km + 200	2.2			0					0	
3 km + 200	3 km + 300	2.5			1					0	
3 km + 300	3 km + 400	2.5			4					0	
3 km + 400	3 km + 500	3.2			0					0	
3 km + 500	3 km + 600	3.4	2.5	-	1	-	-	-	-	0	
3 km + 600	3 km + 700	2.9			0					0	
3 km + 700	3 km + 800	2.5			1					0	
3 km + 800	3 km + 900	2.1			0					0	
3 km + 900	4 km + 0	1.8			0					0	
4 km + 0	4 km + 100	1.6			0					0	
4 km + 100	4 km + 200	1.9			0					0	
4 km + 200	4 km + 300	2.1			0					0	
4 km + 300	4 km + 400	2.2			0					0	
4 km + 400	4 km + 500	2.1			0					0	
4 km + 500	4 km + 600	2.1	2.0	2.4	0	54	10.80	Poor	Rank-3: Poor / Repair (moderate)	0	
4 km + 600	4 km + 700	2.0			0					0	
4 km + 700	4 km + 800	1.9			0					1	
4 km + 800	4 km + 900	1.8			1					0	
4 km + 900	5 km + 0	1.9			0					0	

Major findings should be reported here.

The severe road condition was identified by visual inspection even though IRI values are relatively low. This is the very case that indicates the importance of visual inspection besides IRI measurement.
(Defects were counted at 100m interval.)

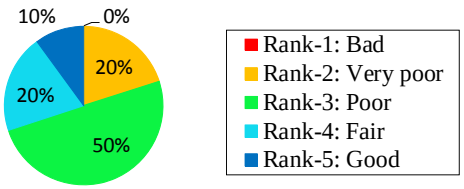
Road section-1 (0-5km) needs repair work (Rank-3: Poor).

Figure-26 Road Inventory (1)

Road Inventory (for Paved Roads)

(1)	Road Name	RN1 (Phnom Penh)				
(2)	Road Length (km)	49.9	Inspected road length:	**49.9** km		
(3)	Pavement Type	AC				
(4)	Date of IRI measurement	24/July/2015				
(5)	Start Point & End Point	Start	PK3+500	End	PK53+400	
(6)	Average IRI (Total Section)	3.0				
(7)	Visual Rating (Total Section)	Indicator-N	2.32	Evaluation	Poor	
(8)	Repair Ratio (**Rank-1+Rank-2+Rank-3**)		**69.9%**			
(9)	Urgency Ratio (**Rank-1+Rank-2**)	**20.0%**	Emergency Ratio (**Rank-1**)	**0.0%**		

Breakdown of the Road Condition



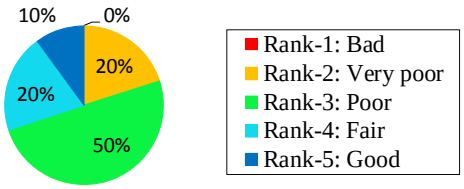
(10) Location			(11) Average IRI			(12) Visual Rating (Per 5.0km)				(13) Road Condition (Per 5.0km)	(14) Remarks	
From	To		Per 100m	Per 1.0km	Per 5.0km	No.of Defects Per 100m	No.of Defects Per 5.0km	N	Evalu-ation		No. of Bridge Joints	Major Findings
5 km + 0	5 km + 100		2.4			0					0	
5 km + 100	5 km + 200		2.3			0					0	
5 km + 200	5 km + 300		1.9			0					0	
5 km + 300	5 km + 400		1.8			0					0	
5 km + 400	5 km + 500		1.8			0					0	
5 km + 500	5 km + 600		1.6	2.0	-	0	-	-	-	-	0	
5 km + 600	5 km + 700		1.6			1					0	
5 km + 700	5 km + 800		2.2			1					0	
5 km + 800	5 km + 900		2.4			0					0	
5 km + 900	6 km + 0		2.3			0					0	
6 km + 0	6 km + 100		2.0			0					0	
6 km + 100	6 km + 200		1.8			0					0	
6 km + 200	6 km + 300		2.2			0					0	
6 km + 300	6 km + 400		2.8			0					0	
6 km + 400	6 km + 500		2.8			0					0	
6 km + 500	6 km + 600		2.7	2.3	-	0	-	-	-	-	0	
6 km + 600	6 km + 700		2.7			0					0	
6 km + 700	6 km + 800		2.4			0					0	
6 km + 800	6 km + 900		1.7			0					0	
6 km + 900	7 km + 0		1.6			0					0	
7 km + 0	7 km + 100		1.7			0					0	
7 km + 100	7 km + 200		1.8			0					0	
7 km + 200	7 km + 300		1.7			0					0	
7 km + 300	7 km + 400		1.8			0					0	
7 km + 400	7 km + 500		2.1			0					0	
7 km + 500	7 km + 600		2.0	1.9	-	0	-	-	-	-	0	
7 km + 600	7 km + 700		2.2			0					0	
7 km + 700	7 km + 800		2.0			0					0	
7 km + 800	7 km + 900		1.6			0					0	
7 km + 900	8 km + 0		1.9			0					0	
8 km + 0	8 km + 100		2.1			0					0	
8 km + 100	8 km + 200		2.0			0					0	
8 km + 200	8 km + 300		2.0			0					0	
8 km + 300	8 km + 400		2.2			0					0	
8 km + 400	8 km + 500		2.3			0					0	
8 km + 500	8 km + 600		2.2	2.4	-	0	-	-	-	-	0	
8 km + 600	8 km + 700		2.5			0					0	
8 km + 700	8 km + 800		2.9			1					0	
8 km + 800	8 km + 900		3.2			1					0	
8 km + 900	9 km + 0		3.1			0					0	
9 km + 0	9 km + 100		2.4			0					0	
9 km + 100	9 km + 200		2.1			0					0	
9 km + 200	9 km + 300		2.6			0					0	
9 km + 300	9 km + 400		2.8			0					0	
9 km + 400	9 km + 500		3.0			0					0	
9 km + 500	9 km + 600		2.9	2.7	2.3	0	4	0.80	Fair	Rank-4: Fair / Repair (small)	0	
9 km + 600	9 km + 700		2.5			0					0	
9 km + 700	9 km + 800		2.4			0					0	
9 km + 800	9 km + 900		3.4			0					0	
9 km + 900	10 km + 0		2.5			0					0	

Figure-27 Road Inventory (2)

Road Inventory (for Paved Roads)

(1)	Road Name	RN1 (Phnom Penh)				
(2)	Road Length (km)	49.9	Inspected road length:	**49.9** km		
(3)	Pavement Type	AC				
(4)	Date of IRI measurement	24/July/2015				
(5)	Start Point & End Point	Start	PK3+500	End	PK53+400	
(6)	Average IRI (Total Section)	3.0				
(7)	Visual Rating (Total Section)	Indicator-N	2.32	Evaluation	Poor	
(8)	Repair Ratio (**Rank-1+Rank-2+Rank-3**)		**69.9%**			
(9)	Urgency Ratio (**Rank-1+Rank-2**)	**20.0%**	Emergency Ratio (**Rank-1**)	**0.0%**		

Breakdown of the Road Condition



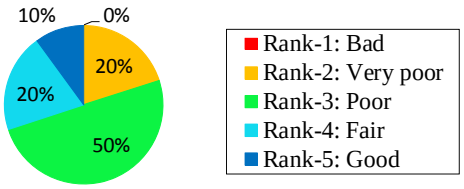
(10) Location		(11) Average IRI			(12) Visual Rating (Per 5.0km)				(13) Road Condition (Per 5.0km)	(14) Remarks	
From	To	Per 100m	Per 1.0km	Per 5.0km	No.of Defects Per 100m	No.of Defects Per 5.0km	N	Evalu-ation		No. of Bridge Joints	Major Findings
10 km + 0	10 km + 100	3.1	2.6	-	1	-	-	-	-	0	
10 km + 100	10 km + 200	2.4			1					0	
10 km + 200	10 km + 300	2.6			0					0	
10 km + 300	10 km + 400	3.0			0					0	
10 km + 400	10 km + 500	2.9			0					0	
10 km + 500	10 km + 600	2.5			0					0	
10 km + 600	10 km + 700	2.2			0					0	
10 km + 700	10 km + 800	2.4			0					0	
10 km + 800	10 km + 900	2.4			0					0	
10 km + 900	11 km + 0	2.2			0					0	
11 km + 0	11 km + 100	2.4	2.3	-	0	-	-	-	-	0	
11 km + 100	11 km + 200	2.4			0					0	
11 km + 200	11 km + 300	2.2			0					0	
11 km + 300	11 km + 400	2.5			0					0	
11 km + 400	11 km + 500	2.6			0					0	
11 km + 500	11 km + 600	2.4			0					0	
11 km + 600	11 km + 700	2.0			0					0	
11 km + 700	11 km + 800	2.1			0					0	
11 km + 800	11 km + 900	2.1			1					0	
11 km + 900	12 km + 0	2.1			0					0	
12 km + 0	12 km + 100	2.2	2.7	-	1	-	-	-	-	0	
12 km + 100	12 km + 200	2.2			1					0	
12 km + 200	12 km + 300	2.3			0					0	
12 km + 300	12 km + 400	2.6			0					0	
12 km + 400	12 km + 500	2.8			0					0	
12 km + 500	12 km + 600	2.7			0					0	
12 km + 600	12 km + 700	2.7			0					0	
12 km + 700	12 km + 800	2.9			0					0	
12 km + 800	12 km + 900	3.3			0					0	
12 km + 900	13 km + 0	3.2			0					0	
13 km + 0	13 km + 100	2.7	2.5	-	1	-	-	-	-	0	
13 km + 100	13 km + 200	2.5			3					0	
13 km + 200	13 km + 300	2.5			1					0	
13 km + 300	13 km + 400	2.5			0					0	
13 km + 400	13 km + 500	2.6			0					0	
13 km + 500	13 km + 600	2.6			0					0	
13 km + 600	13 km + 700	2.3			0					0	
13 km + 700	13 km + 800	2.1			0					0	
13 km + 800	13 km + 900	2.3			3					0	
13 km + 900	14 km + 0	2.8			2					0	
14 km + 0	14 km + 100	2.9	2.5	2.5	0	16	3.20	Poor	Rank-3: Poor	0	
14 km + 100	14 km + 200	2.5			0					0	
14 km + 200	14 km + 300	2.3			0					0	
14 km + 300	14 km + 400	2.2			0					0	
14 km + 400	14 km + 500	2.2			0					0	
14 km + 500	14 km + 600	2.3			0				Repair (moderate)	0	
14 km + 600	14 km + 700	2.3			0					0	
14 km + 700	14 km + 800	2.3			0					0	
14 km + 800	14 km + 900	2.7			0					0	
14 km + 900	15 km + 0	3.0			1					0	

Figure-28 Road Inventory (3)

Road Inventory (for Paved Roads)

(1)	Road Name	RN1 (Phnom Penh)				
(2)	Road Length (km)	49.9	Inspected road length:	**49.9** km		
(3)	Pavement Type	AC				
(4)	Date of IRI measurement	24/July/2015				
(5)	Start Point & End Point	Start	PK3+500	End	PK53+400	
(6)	Average IRI (Total Section)	3.0				
(7)	Visual Rating (Total Section)	Indicator-N	2.32	Evaluation	Poor	
(8)	Repair Ratio (**Rank-1+Rank-2+Rank-3**)		**69.9%**			
(9)	Urgency Ratio (**Rank-1+Rank-2**)	**20.0%**	Emergency Ratio (**Rank-1**)	**0.0%**		

Breakdown of the Road Condition



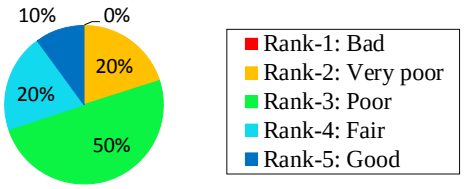
(10) Location				(11) Average IRI			(12) Visual Rating (Per 5.0km)				(13) Road Condition (Per 5.0km)	(14) Remarks	
From		To		Per 100m	Per 1.0km	Per 5.0km	No.of Defects Per 100m	No.of Defects Per 5.0km	N	Evalu-ation		No. of Bridge Joints	Major Findings
15 km + 0		15 km + 100		2.7			1					0	
15 km + 100		15 km + 200		2.2			0					0	
15 km + 200		15 km + 300		1.8			0					0	
15 km + 300		15 km + 400		2.0			0					0	
15 km + 400		15 km + 500		2.2			0					0	
15 km + 500		15 km + 600		2.2	2.2	-	0	-	-	-	-	0	
15 km + 600		15 km + 700		2.5			0					0	
15 km + 700		15 km + 800		2.2			0					0	
15 km + 800		15 km + 900		2.3			0					0	
15 km + 900		16 km + 0		2.3			0					0	
16 km + 0		16 km + 100		2.0			0					0	
16 km + 100		16 km + 200		2.2			0					0	
16 km + 200		16 km + 300		2.3			0					0	
16 km + 300		16 km + 400		2.6			0					0	
16 km + 400		16 km + 500		2.7			0					0	
16 km + 500		16 km + 600		2.5	2.4	-	0	-	-	-	-	0	
16 km + 600		16 km + 700		2.1			0					0	
16 km + 700		16 km + 800		2.5			0					0	
16 km + 800		16 km + 900		3.0			0					0	
16 km + 900		17 km + 0		2.6			0					0	
17 km + 0		17 km + 100		2.6			0					0	
17 km + 100		17 km + 200		3.2			0					0	
17 km + 200		17 km + 300		2.8			0					0	
17 km + 300		17 km + 400		2.2			1					0	
17 km + 400		17 km + 500		2.0			0					0	
17 km + 500		17 km + 600		1.7	2.4	-	0	-	-	-	-	0	
17 km + 600		17 km + 700		2.1			1					0	
17 km + 700		17 km + 800		2.7			0					0	
17 km + 800		17 km + 900		2.7			0					0	
17 km + 900		18 km + 0		2.3			0					0	
18 km + 0		18 km + 100		2.0			0					0	
18 km + 100		18 km + 200		2.0			0					0	
18 km + 200		18 km + 300		2.2			0					0	
18 km + 300		18 km + 400		2.5			0					0	
18 km + 400		18 km + 500		2.6			0					0	
18 km + 500		18 km + 600		2.7	2.5	-	0	-	-	-	-	0	
18 km + 600		18 km + 700		2.5			0					0	
18 km + 700		18 km + 800		2.7			0					0	
18 km + 800		18 km + 900		2.9			0					0	
18 km + 900		19 km + 0		2.8			0					0	
19 km + 0		19 km + 100		2.7			0					0	
19 km + 100		19 km + 200		2.7			0					0	
19 km + 200		19 km + 300		2.4			0					0	
19 km + 300		19 km + 400		2.6			0					0	
19 km + 400		19 km + 500		2.7			0					0	
19 km + 500		19 km + 600		2.7	2.7	2.5	0	3	0.60	Fair	Rank-4: Fair Repair (small)	0	
19 km + 600		19 km + 700		2.8			0					0	
19 km + 700		19 km + 800		3.0			0					0	
19 km + 800		19 km + 900		2.9			0					0	
19 km + 900		20 km + 0		2.7			0					0	

Figure-29 Road Inventory (4)

Road Inventory (for Paved Roads)

(1)	Road Name	RN1 (Phnom Penh)				
(2)	Road Length (km)	49.9	Inspected road length:	**49.9** km		
(3)	Pavement Type	AC				
(4)	Date of IRI measurement	24/July/2015				
(5)	Start Point & End Point	Start	PK3+500	End	PK53+400	
(6)	Average IRI (Total Section)	3.0				
(7)	Visual Rating (Total Section)	Indicator-N	2.32	Evaluation	Poor	
(8)	Repair Ratio (**Rank-1+Rank-2+Rank-3**)		**69.9%**			
(9)	Urgency Ratio (**Rank-1+Rank-2**)	**20.0%**	Emergency Ratio (**Rank-1**)	**0.0%**		

Breakdown of the Road Condition



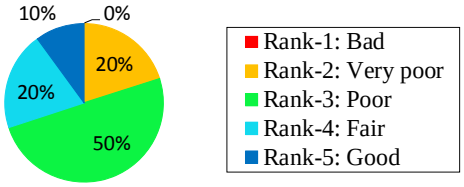
(10) Location		(11) Average IRI			(12) Visual Rating (Per 5.0km)				(13) Road Condition (Per 5.0km)	(14) Remarks	
From	To	Per 100m	Per 1.0km	Per 5.0km	No.of Defects Per 100m	No.of Defects Per 5.0km	N	Evalu-ation		No. of Bridge Joints	Major Findings
20 km + 0	20 km + 100	3.0			0					0	
20 km + 100	20 km + 200	2.8			0					0	
20 km + 200	20 km + 300	3.0			1					0	
20 km + 300	20 km + 400	3.1			1					0	
20 km + 400	20 km + 500	3.5			0					0	
20 km + 500	20 km + 600	3.3	3.0	-	0	-	-	-	-	0	
20 km + 600	20 km + 700	2.5			0					0	
20 km + 700	20 km + 800	2.5			0					0	
20 km + 800	20 km + 900	2.8			0					0	
20 km + 900	21 km + 0	3.1			0					0	
21 km + 0	21 km + 100	3.1			0					0	
21 km + 100	21 km + 200	2.6			0					0	
21 km + 200	21 km + 300	2.4			0					0	
21 km + 300	21 km + 400	2.5			0					0	
21 km + 400	21 km + 500	2.5			0					0	
21 km + 500	21 km + 600	2.6	2.6	-	0	-	-	-	-	0	
21 km + 600	21 km + 700	2.6			0					0	
21 km + 700	21 km + 800	2.6			0					0	
21 km + 800	21 km + 900	2.4			0					0	
21 km + 900	22 km + 0	3.2			0					0	
22 km + 0	22 km + 100	3.1			0					0	
22 km + 100	22 km + 200	2.7			0					0	
22 km + 200	22 km + 300	2.4			0					0	
22 km + 300	22 km + 400	2.4			0					0	
22 km + 400	22 km + 500	2.3			0					0	
22 km + 500	22 km + 600	2.8	2.8	-	0	-	-	-	-	0	
22 km + 600	22 km + 700	3.2			0					0	
22 km + 700	22 km + 800	3.0			0					0	
22 km + 800	22 km + 900	2.8			0					0	
22 km + 900	23 km + 0	2.8			0					0	
23 km + 0	23 km + 100	2.8			0					0	
23 km + 100	23 km + 200	3.0			0					0	
23 km + 200	23 km + 300	3.0			0					0	
23 km + 300	23 km + 400	2.9			0					0	
23 km + 400	23 km + 500	2.8			0					0	
23 km + 500	23 km + 600	3.0	2.9	-	0	-	-	-	-	0	
23 km + 600	23 km + 700	3.0			0					0	
23 km + 700	23 km + 800	2.9			0					0	
23 km + 800	23 km + 900	2.6			0					0	
23 km + 900	24 km + 0	3.3			0					0	
24 km + 0	24 km + 100	3.6			0					0	
24 km + 100	24 km + 200	3.6			0					0	
24 km + 200	24 km + 300	4.1			0					0	
24 km + 300	24 km + 400	3.6			0					0	
24 km + 400	24 km + 500	4.4			0					0	
24 km + 500	24 km + 600	3.9	3.8	3.0	0	2	0.40	Fairly good	Rank-5: Good	0	
24 km + 600	24 km + 700	3.7			0					0	
24 km + 700	24 km + 800	3.8			0				Regular inspection	0	
24 km + 800	24 km + 900	3.4			0					0	
24 km + 900	25 km + 0	4.4			0					0	

Figure-30 Road Inventory (5)

Road Inventory (for Paved Roads)

(1)	Road Name	RN1 (Phnom Penh)				
(2)	Road Length (km)	49.9	Inspected road length:	**49.9** km		
(3)	Pavement Type	AC				
(4)	Date of IRI measurement	24/July/2015				
(5)	Start Point & End Point	Start	PK3+500	End	PK53+400	
(6)	Average IRI (Total Section)	3.0				
(7)	Visual Rating (Total Section)	Indicator-N	2.32	Evaluation	Poor	
(8)	Repair Ratio (**Rank-1+Rank-2+Rank-3**)		**69.9%**			
(9)	Urgency Ratio (**Rank-1+Rank-2**)	**20.0%**	Emergency Ratio (**Rank-1**)	**0.0%**		

Breakdown of the Road Condition



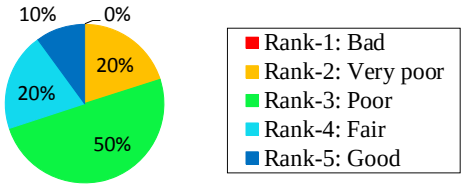
(10) Location		(11) Average IRI			(12) Visual Rating (Per 5.0km)				(13) Road Condition (Per 5.0km)	(14) Remarks	
From	To	Per 100m	Per 1.0km	Per 5.0km	No.of Defects Per 100m	No.of Defects Per 5.0km	N	Evalu-ation		No. of Bridge Joints	Major Findings
25 km + 0	25 km + 100	4.3			0					0	
25 km + 100	25 km + 200	3.3			1					0	
25 km + 200	25 km + 300	3.1			1					0	
25 km + 300	25 km + 400	2.7			0					0	
25 km + 400	25 km + 500	2.4			0					0	
25 km + 500	25 km + 600	2.5	3.0	-	0	-	-	-	-	0	
25 km + 600	25 km + 700	2.6			0					0	
25 km + 700	25 km + 800	2.9			0					0	
25 km + 800	25 km + 900	3.1			0					0	
25 km + 900	26 km + 0	2.7			0					0	
26 km + 0	26 km + 100	2.6			0					0	
26 km + 100	26 km + 200	2.6			0					0	
26 km + 200	26 km + 300	2.6			0					0	
26 km + 300	26 km + 400	2.7			0					0	
26 km + 400	26 km + 500	2.6			0					0	
26 km + 500	26 km + 600	2.5	2.6	-	0	-	-	-	-	0	
26 km + 600	26 km + 700	2.5			0					0	
26 km + 700	26 km + 800	2.6			0					0	
26 km + 800	26 km + 900	2.6			0					0	
26 km + 900	27 km + 0	2.7			0					0	
27 km + 0	27 km + 100	2.6			1					0	
27 km + 100	27 km + 200	2.5			1					0	
27 km + 200	27 km + 300	3.4			0					0	
27 km + 300	27 km + 400	3.7			0					0	
27 km + 400	27 km + 500	3.1			0					0	
27 km + 500	27 km + 600	1.9	2.6	-	0	-	-	-	-	0	
27 km + 600	27 km + 700	2.1			0					0	
27 km + 700	27 km + 800	2.1			0					0	
27 km + 800	27 km + 900	2.2			0					0	
27 km + 900	28 km + 0	2.2			0					0	
28 km + 0	28 km + 100	2.2			0					0	
28 km + 100	28 km + 200	2.5			0					0	
28 km + 200	28 km + 300	3.0			1					0	
28 km + 300	28 km + 400	2.7			0					0	
28 km + 400	28 km + 500	2.5			1					0	
28 km + 500	28 km + 600	2.4	2.9	-	1	-	-	-	-	0	
28 km + 600	28 km + 700	3.4			0					0	
28 km + 700	28 km + 800	3.8			0					0	
28 km + 800	28 km + 900	3.3			0					0	
28 km + 900	29 km + 0	3.0			0					0	
29 km + 0	29 km + 100	2.7			0					0	
29 km + 100	29 km + 200	2.8			0					0	
29 km + 200	29 km + 300	2.5			0					0	
29 km + 300	29 km + 400	3.0			0					0	
29 km + 400	29 km + 500	3.7			0					0	
29 km + 500	29 km + 600	3.1	3.0	2.8	0	7	1.40	Poor	Rank-3: Poor Repair (moderate)	0	
29 km + 600	29 km + 700	2.7			0					0	
29 km + 700	29 km + 800	2.9			0					0	
29 km + 800	29 km + 900	3.1			0					0	
29 km + 900	30 km + 0	3.2			0					0	

Figure-31 Road Inventory (6)

Road Inventory (for Paved Roads)

(1)	Road Name	RN1 (Phnom Penh)				
(2)	Road Length (km)	49.9	Inspected road length:	**49.9** km		
(3)	Pavement Type	AC				
(4)	Date of IRI measurement	24/July/2015				
(5)	Start Point & End Point	Start	PK3+500	End	PK53+400	
(6)	Average IRI (Total Section)	3.0				
(7)	Visual Rating (Total Section)	Indicator-N	2.32	Evaluation	Poor	
(8)	Repair Ratio (**Rank-1+Rank-2+Rank-3**)		**69.9%**			
(9)	Urgency Ratio (**Rank-1+Rank-2**)	**20.0%**	Emergency Ratio (**Rank-1**)	**0.0%**		

Breakdown of the Road Condition



(10) Location		(11) Average IRI			(12) Visual Rating (Per 5.0km)				(13) Road Condition (Per 5.0km)	(14) Remarks	
From	To	Per 100m	Per 1.0km	Per 5.0km	No.of Defects Per 100m	No.of Defects Per 5.0km	N	Evalu-ation		No. of Bridge Joints	Major Findings
30 km + 0	30 km + 100	2.9			0					0	
30 km + 100	30 km + 200	2.7			0					0	
30 km + 200	30 km + 300	2.9			0					0	
30 km + 300	30 km + 400	3.1			0					0	
30 km + 400	30 km + 500	2.7			0					0	
30 km + 500	30 km + 600	2.1	2.7	-	0	-	-	-	-	0	
30 km + 600	30 km + 700	2.3			0					0	
30 km + 700	30 km + 800	2.6			0					0	
30 km + 800	30 km + 900	2.9			0					0	
30 km + 900	31 km + 0	2.9			0					0	
31 km + 0	31 km + 100	2.9			0					0	Bumps due to projected lane marks
31 km + 100	31 km + 200	3.0			0					0	
31 km + 200	31 km + 300	2.8			0					0	
31 km + 300	31 km + 400	3.3			0					0	
31 km + 400	31 km + 500	3.5			0					0	
31 km + 500	31 km + 600	3.3	3.4	-	0	-	-	-	-	0	
31 km + 600	31 km + 700	3.3								0	
31 km + 700	31 km + 800	3.5								0	
31 km + 800	31 km + 900	4.3								0	
31 km + 900	32 km + 0	4.2								0	
32 km + 0	32 km + 100	4.3			0					0	Bumps due to projected lane marks
32 km + 100	32 km + 200	5.3			0					0	
32 km + 200	32 km + 300	5.2			0					0	
32 km + 300	32 km + 400	4.0			0					0	
32 km + 400	32 km + 500	3.0			0					0	
32 km + 500	32 km + 600	2.4	3.7	-	0	-	-	-	-	0	
32 km + 600	32 km + 700	2.5			0					0	
32 km + 700	32 km + 800	2.9			0					0	
32 km + 800	32 km + 900	3.4			0					0	
32 km + 900	33 km + 0	4.2			0					0	
33 km + 0	33 km + 100	4.0			0					0	Bumps due to rough road surface
33 km + 100	33 km + 200	4.1			0					0	
33 km + 200	33 km + 300	5.0			0					0	
33 km + 300	33 km + 400	5.0			0					0	
33 km + 400	33 km + 500	5.2			0					0	
33 km + 500	33 km + 600	4.8	4.6	-	0	-	-	-	-	0	
33 km + 600	33 km + 700	4.1			0					0	
33 km + 700	33 km + 800	4.7			0					0	
33 km + 800	33 km + 900	4.8			0					0	
33 km + 900	34 km + 0	4.1			0					0	
34 km + 0	34 km + 100	3.8			0					0	Bumps due to rough road surface
34 km + 100	34 km + 200	3.9			0					0	
34 km + 200	34 km + 300	4.7			0					0	
34 km + 300	34 km + 400	5.2			0					0	
34 km + 400	34 km + 500	4.8			0					0	
34 km + 500	34 km + 600	4.1	4.4	3.8	0	2	0.40	Fairly good	Rank-3: Poor / Repair (moderate)	0	
34 km + 600	34 km + 700	4.2			0					0	
34 km + 700	34 km + 800	4.3			1					0	
34 km + 800	34 km + 900	4.6			1					0	
34 km + 900	35 km + 0	4.5			0					0	

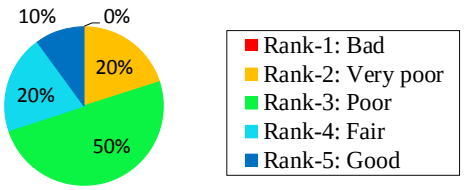
Reasoning of large IRI values is very important in order to know actual road conditions.

Figure-32 Road Inventory (7)

Road Inventory (for Paved Roads)

(1)	Road Name	RN1 (Phnom Penh)				
(2)	Road Length (km)	49.9	Inspected road length:	**49.9** km		
(3)	Pavement Type	AC				
(4)	Date of IRI measurement	24/July/2015				
(5)	Start Point & End Point	Start	PK3+500	End	PK53+400	
(6)	Average IRI (Total Section)	3.0				
(7)	Visual Rating (Total Section)	Indicator-N	2.32	Evaluation	Poor	
(8)	Repair Ratio (**Rank-1+Rank-2+Rank-3**)		**69.9%**			
(9)	Urgency Ratio (**Rank-1+Rank-2**)	**20.0%**	Emergency Ratio (**Rank-1**)	**0.0%**		

Breakdown of the Road Condition



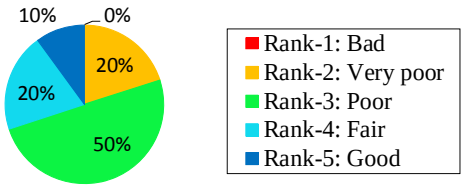
(10) Location		(11) Average IRI			(12) Visual Rating (Per 5.0km)				(13) Road Condition (Per 5.0km)	(14) Remarks	
From	To	Per 100m	Per 1.0km	Per 5.0km	No.of Defects Per 100m	No.of Defects Per 5.0km	N	Evalu-ation		No. of Bridge Joints	Major Findings
35 km + 0	35 km + 100	3.9			0					0	Bumps due to rough road surface
35 km + 100	35 km + 200	3.9			0					0	
35 km + 200	35 km + 300	4.2			2					0	
35 km + 300	35 km + 400	3.9			3					0	
35 km + 400	35 km + 500	3.1	3.6	-	0	-	-	-	-	0	
35 km + 500	35 km + 600	2.8			0					0	
35 km + 600	35 km + 700	3.5			4					0	
35 km + 700	35 km + 800	3.7			1					0	
35 km + 800	35 km + 900	3.5			0					0	
35 km + 900	36 km + 0	3.8			0					0	
36 km + 0	36 km + 100	4.2			0					0	Bumps due to rough road surface
36 km + 100	36 km + 200	3.8			0					0	
36 km + 200	36 km + 300	3.5			0					0	
36 km + 300	36 km + 400	4.0			0					0	
36 km + 400	36 km + 500	3.7	4.0	-	0	-	-	-	-	0	
36 km + 500	36 km + 600	3.3			0					0	
36 km + 600	36 km + 700	3.8			0					0	
36 km + 700	36 km + 800	5.0			0					0	
36 km + 800	36 km + 900	5.0			0					0	
36 km + 900	37 km + 0	3.5			0					0	
37 km + 0	37 km + 100	3.2			0					0	Bumps due to rough road surface
37 km + 100	37 km + 200	3.8			0					0	
37 km + 200	37 km + 300	4.8			0					0	
37 km + 300	37 km + 400	5.6			0					0	
37 km + 400	37 km + 500	4.1			0					0	
37 km + 500	37 km + 600	3.4	4.4	-	0	-	-	-	-	0	
37 km + 600	37 km + 700	4.0			0					0	
37 km + 700	37 km + 800	4.9			0					0	
37 km + 800	37 km + 900	5.1			0					0	
37 km + 900	38 km + 0	4.8			0					0	
38 km + 0	38 km + 100	4.6			0					0	Bumps due to rough road surface
38 km + 100	38 km + 200	4.2			0					0	
38 km + 200	38 km + 300	4.0			0					0	
38 km + 300	38 km + 400	4.4			0					0	
38 km + 400	38 km + 500	4.6	4.3	-	1	-	-	-	-	0	
38 km + 500	38 km + 600	4.1			0					0	
38 km + 600	38 km + 700	4.2			1					0	
38 km + 700	38 km + 800	4.7			0					0	
38 km + 800	38 km + 900	4.3			0					0	
38 km + 900	39 km + 0	4.4			0					0	
39 km + 0	39 km + 100	5.3			0					0	Bumps due to rough road surface
39 km + 100	39 km + 200	4.8			0					0	
39 km + 200	39 km + 300	3.5			0					0	
39 km + 300	39 km + 400	3.4			0					0	
39 km + 400	39 km + 500	4.8			0					0	
39 km + 500	39 km + 600	4.9	4.3	4.1	0	12	2.40	Poor	Rank-2: Very poor Repair/ Resurfacing	0	
39 km + 600	39 km + 700	3.9			0					0	
39 km + 700	39 km + 800	4.6			0					0	
39 km + 800	39 km + 900	4.5			0					0	
39 km + 900	40 km + 0	3.4			0					0	

Figure-33 Road Inventory (8)

Road Inventory (for Paved Roads)

(1)	Road Name	RN1 (Phnom Penh)				
(2)	Road Length (km)	49.9	Inspected road length:	**49.9** km		
(3)	Pavement Type	AC				
(4)	Date of IRI measurement	24/July/2015				
(5)	Start Point & End Point	Start	PK3+500	End	PK53+400	
(6)	Average IRI (Total Section)	3.0				
(7)	Visual Rating (Total Section)	Indicator-N	2.32	Evaluation	Poor	
(8)	Repair Ratio (**Rank-1+Rank-2+Rank-3**)		**69.9%**			
(9)	Urgency Ratio (**Rank-1+Rank-2**)	**20.0%**	Emergency Ratio (**Rank-1**)	**0.0%**		

Breakdown of the Road Condition



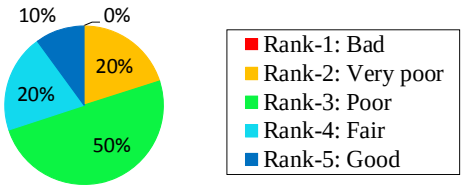
(10) Location				(11) Average IRI			(12) Visual Rating (Per 5.0km)				(13) Road Condition (Per 5.0km)	(14) Remarks	
From		To		Per 100m	Per 1.0km	Per 5.0km	No.of Defects Per 100m	No.of Defects Per 5.0km	N	Evalu-ation		No. of Bridge Joints	Major Findings
40 km + 0		40 km + 100		3.0			0					0	Bumps due to rough road surface
40 km + 100		40 km + 200		3.9			0					0	
40 km + 200		40 km + 300		4.4			0					0	
40 km + 300		40 km + 400		3.7			0					0	
40 km + 400		40 km + 500		3.4	3.4	-	0	-	-	-		0	
40 km + 500		40 km + 600		3.2			0				-	0	
40 km + 600		40 km + 700		3.1			0					0	
40 km + 700		40 km + 800		3.2			0					0	
40 km + 800		40 km + 900		3.2			0					0	
40 km + 900		41 km + 0		3.2			0					0	
41 km + 0		41 km + 100		3.3			0					0	
41 km + 100		41 km + 200		3.6			0					0	
41 km + 200		41 km + 300		3.7			1					0	
41 km + 300		41 km + 400		3.5			2					0	
41 km + 400		41 km + 500		3.8			0					0	
41 km + 500		41 km + 600		3.6	3.6	-	0	-	-	-		0	
41 km + 600		41 km + 700		3.7			0				-	0	
41 km + 700		41 km + 800		4.0			0					0	
41 km + 800		41 km + 900		3.8			0					0	
41 km + 900		42 km + 0		3.4			0					0	
42 km + 0		42 km + 100		3.1			0					0	
42 km + 100		42 km + 200		3.5			0					0	
42 km + 200		42 km + 300		4.2			0					0	
42 km + 300		42 km + 400		3.9			0					0	
42 km + 400		42 km + 500		3.3			0					0	
42 km + 500		42 km + 600		3.3	3.2	-	0	-	-	-		0	
42 km + 600		42 km + 700		2.9			0				-	0	
42 km + 700		42 km + 800		2.5			0					0	
42 km + 800		42 km + 900		2.5			0					0	
42 km + 900		43 km + 0		2.9			0					0	
43 km + 0		43 km + 100		3.2			0					0	Bumps due to rough road surface
43 km + 100		43 km + 200		4.7			2					0	
43 km + 200		43 km + 300		5.1			0					0	
43 km + 300		43 km + 400		3.5			0					0	
43 km + 400		43 km + 500		2.9			0					0	
43 km + 500		43 km + 600		2.8	3.2	-	0	-	-	-		0	
43 km + 600		43 km + 700		2.6			1				-	0	
43 km + 700		43 km + 800		2.4			1					0	
43 km + 800		43 km + 900		2.5			1					0	
43 km + 900		44 km + 0		2.7			0					0	
44 km + 0		44 km + 100		3.5			0					0	Bumps due insufficient bridge expansion joints
44 km + 100		44 km + 200		7.7			0					0	
44 km + 200		44 km + 300		9.2			0				Rank-2: Very poor	0	
44 km + 300		44 km + 400		5.4			0					0	
44 km + 400		44 km + 500		3.2			0					0	
44 km + 500		44 km + 600		3.5	4.7	3.6	0	10	2.00	Poor		0	
44 km + 600		44 km + 700		3.3			0				Repair/ Resurfacing	0	
44 km + 700		44 km + 800		2.9			0					0	
44 km + 800		44 km + 900		3.5			1					0	
44 km + 900		45 km + 0		5.1			1					0	

Figure-34 Road Inventory (9)

Road Inventory (for Paved Roads)

(1)	Road Name	RN1 (Phnom Penh)				
(2)	Road Length (km)	49.9	Inspected road length:	**49.9** km		
(3)	Pavement Type	AC				
(4)	Date of IRI measurement	24/July/2015				
(5)	Start Point & End Point	Start	PK3+500	End	PK53+400	
(6)	Average IRI (Total Section)	3.0				
(7)	Visual Rating (Total Section)	Indicator-N	2.32	Evaluation	Poor	
(8)	Repair Ratio (**Rank-1+Rank-2+Rank-3**)		**69.9%**			
(9)	Urgency Ratio (**Rank-1+Rank-2**)	**20.0%**	Emergency Ratio (**Rank-1**)	**0.0%**		

Breakdown of the Road Condition



(10) Location		(11) Average IRI			(12) Visual Rating (Per 5.0km)				(13) Road Condition (Per 5.0km)	(14) Remarks	
From	To	Per 100m	Per 1.0km	Per 5.0km	No.of Defects Per 100m	No.of Defects Per 5.0km	N	Evaluation		No. of Bridge Joints	Major Findings
45 km + 0	45 km + 100	5.7			0					0	Bumps due to deformation
45 km + 100	45 km + 200	3.9			0					0	
45 km + 200	45 km + 300	3.7			1					0	
45 km + 300	45 km + 400	3.6			0					0	
45 km + 400	45 km + 500	2.9	3.4	-	0	-	-	-	-	0	
45 km + 500	45 km + 600	3.2			0					0	
45 km + 600	45 km + 700	3.5			0					0	
45 km + 700	45 km + 800	2.9			0					0	
45 km + 800	45 km + 900	2.3			0					0	
45 km + 900	46 km + 0	2.5			0					0	
46 km + 0	46 km + 100	2.7			0					0	
46 km + 100	46 km + 200	3.2			0					0	
46 km + 200	46 km + 300	4.7			0					0	
46 km + 300	46 km + 400	4.3			0					0	
46 km + 400	46 km + 500	2.6	3.2	-	0	-	-	-	-	0	
46 km + 500	46 km + 600	2.3			0					0	
46 km + 600	46 km + 700	2.9			0					0	
46 km + 700	46 km + 800	3.1			0					0	
46 km + 800	46 km + 900	2.9			0					0	
46 km + 900	47 km + 0	2.8			0					0	
47 km + 0	47 km + 100	3.3			0					0	
47 km + 100	47 km + 200	3.4			0					0	
47 km + 200	47 km + 300	3.1			0					0	
47 km + 300	47 km + 400	2.9			0					0	
47 km + 400	47 km + 500	2.7	3.1	-	0	-	-	-	-	0	
47 km + 500	47 km + 600	2.7			0					0	
47 km + 600	47 km + 700	2.8			0					2	
47 km + 700	47 km + 800	3.2			0					0	
47 km + 800	47 km + 900	3.6			0					0	
47 km + 900	48 km + 0	3.1			0					0	
48 km + 0	48 km + 100	3.2			0					0	
48 km + 100	48 km + 200	3.6			1					0	
48 km + 200	48 km + 300	3.5			1					0	
48 km + 300	48 km + 400	3.6			2					0	
48 km + 400	48 km + 500	4.0	3.4	-	0	-	-	-	-	0	
48 km + 500	48 km + 600	3.9			0					0	
48 km + 600	48 km + 700	3.4			1					0	
48 km + 700	48 km + 800	3.0			0					0	
48 km + 800	48 km + 900	2.7			0					0	
48 km + 900	49 km + 0	2.6			0					0	
49 km + 0	49 km + 100	2.9			0					0	
49 km + 100	49 km + 200	3.2			0					0	
49 km + 200	49 km + 300	3.0			0					0	
49 km + 300	49 km + 400	4.2			0					0	
49 km + 400	49 km + 500	5.4	3.7	3.3	0	6	1.20	Poor	Rank-3: Poor	0	
49 km + 500	49 km + 600	4.5			0					0	
49 km + 600	49 km + 700	3.1			0				Repair (moderate)	0	
49 km + 700	49 km + 800	3.5			0					0	
49 km + 800	49 km + 900	3.6			0					0	
49 km + 900	50 km + 0										

Figure-35 Road Inventory (10)

8.5 Step.3: Preparation of Road Lists with Evaluation Results

The inspection results have been summarized in the road list shown in Table-28. The list can be utilized for prioritization of target roads for maintenance work according to the criteria shown in Table-13. The list should be prepared province by province.

Table-28 Road List with Evaluation Results

Road Name	No. of Lanes	Pavement Type	Road Length (km)	Overall Condition		Repair Neccessity (%)		
				Ave. IRI	Indicator-N (visual rating)	Repair Ratio *1	Urgency Ratio *2	Emergency Ratio *3
RN1 (Phnom Penh)	2	AC	49.9	3.03	2.32: Poor	69.9	20.0	0.0

1*: "Repair ratio" is ratio of "Rank-1+ Rank-2+ Rank-3" to inspected road length.
2*: "Urgency ratio" is ratio of "Rank-1+ Rank-2" to inspected road length.
3*: "Emergency Ratio" is the ratio of "Rank-1" to inspected road length.

8.6 Step.4: Selection of Maintenance Methods and Cost Estimate

8.6.1 Confirmation of Basic Road Information

Prior to selection of maintenance methods and cost estimation, basic road information such as 1) road name, 2) road length, 3) pavement type, 4) the number of lanes, 5) carriageway width, and 6) road class has to be confirmed as shown in Table-29. In regard to carriageway width, it should be noted that carriageway here is defined to be width for 2 lanes only. Standard width for 2 lanes is 7.0m. Even if target roads have 4 lanes, the carriageway width has to be set by 2 lanes.

Table-29 Confirmation of Basic Road Information

(1)	Road Name	RN1 (Phnom Penh)
(2)	Road Length (km)	49.9
(3)	Pavement Type	AC
(4)	The number of Lanes	2
(5)	Carriageway width (m)	7.0
(6)	Road Class	1-digit roads

Note: - Standard carriageway width is 7.0m (2 lanes).
- "Carriageway width" is set by 2 lanes even if it has 4 lanes.

8.6.2 Selection of Maintenance Methods for Carriageways

Maintenance methods are selected for road sections evaluated as Rank-1 through Rank-3. In this case, Routine Maintenance was selected for the entire road section as shown in Table-30.

Table-30 Selection of Maintenance Methods

Road Condtion		Percentage (%)	Distance (km)	Maintenance Category	
Rank-1: Bad	Method-1	**0.0**	**0.0**	Chap.21	Investment (Excluded)
	Method-2	**0.0**	0.0	Chap.61	Routine Maintenance
	Method-3	**0.0**	0.0		Periodic Maintenance
Rank-2: Very poor	Method-1	**20.0**	10.0	Chap.61	Routine Maintenance
	Method-2	**0.0**	0.0		Periodic Maintenance
Rank-3: Poor	Method-1	**49.9**	24.9	Chap.61	Routine Maintenance
	Method-2	**0.0**	0.0		Periodic Maintenance
Rank-4: Fair		**20.0**	10.0	Chap.61	Routine Maintenance
Rank-5: Good		**10.1**	5.0		

There're no Rank-1 sections.

Selection of Method-1 (Routine Maintenance) for Rank-2 sections

Selection of Method-1 (Routine Maintenance) for Rank-3 sections

8.6.3 Cost Estimation for Carriageways

(1) Determination of Unit Cost of Each Maintenance Method

Unit costs of routine maintenance have been determined as shown in Figure-36. Unit prices of 3 work code items were set with past project information.

Rank-2 (Very poor):

- Method-1 (Routine Maintenance): Repair (severe)

Code	Maintenance Work	Unit	Price ($)	Quantity	Cost ($/5km)		
1131	Join and Crack Filling	m2	3.63	1,522.5	5,526.68		
1150	Shape Correction	m2	8.17	2,300.3	18,793.04		
1100	Pothole Repair by AC	m2	11.68	123.0	1,436.64		Unit cost
				($/5km)	25,756.36	($/km)	5,151.27

Rank-3 (Poor):

- Method-1 (Routine Maintenance): Repair (moderate)

Code	Maintenance Work	Unit	Price ($)	Quantity	Cost ($/5km)		
1131	Join and Crack Filling	m2	3.63	1,496.3	5,431.39		
1150	Shape Correction	m2	8.17	1,317.3	10,762.34		
1100	Pothole Repair by AC	m2	11.68	123.0	1,436.64		Unit cost
				($/5km)	17,630.37	($/km)	3,526.07

Rank-4 (Fair): Repair (small) and preventive maintenance

Code	Maintenance Work	Unit	Price ($)	Quantity	Cost ($/5km)		
1131	Join and Crack Filling	m2	3.63	699.8	2,540.09		
1150	Shape Correction	m2	8.17	543.0	4,436.31		
1100	Pothole Repair by AC	m2	11.68	0.0	0.00		Unit cost
				($/5km)	6,976.40	($/km)	1,395.28

Rank-5 (Good): Preventive maintenance

Code	Maintenance Work	Unit	Price ($)	Quantity	Cost ($/5km)		
1131	Join and Crack Filling	m2	3.63	699.8	2,540.09		
1150	Shape Correction	m2	8.17	543.0	4,436.31		
1100	Pothole Repair by AC	m2	11.68	0.0	0.00		Unit cost
				($/5km)	6,976.40	($/km)	1,395.28

To be determined, based on past projects' information

Standardized quantities

Figure-36 Determination of Unit Cost of Each Maintenance Method

(2) Cost Estimation

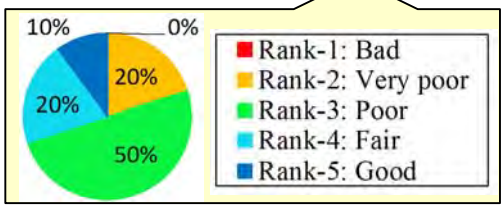
Approximate maintenance cost for the carriageway has been estimated as shown in Table-31. Also, breakdown of road conditions and maintenance costs for the carriageway is shown in Table-32.

Table-31 Cost Estimate for the Maintenance Plan

Code	Maintenance Work	Unit	Quantity	Price ($)	Cost ($)		
1131	Join and Crack Filling	m2	12,595.58	3.63	45,721.94		
1150	Shape Correction	m2	12,789.65	8.17	104,491.47		
1100	Pothole Repair by AC	m2	858.54	11.68	10,027.75		
-	Overlay with AC	m2	0.00	10.00	0.00		Unit cost
				Total: ($)	160,241.16	($/km)	3,211

Table-32 Breakdown of Road Conditions and Maintenance Costs for the Carriageway

Road Condtion		Percentage (%)	Distance (km)	Unit Cost ($/km)	Cost ($)	Maintenance Category	
Rank-1: Bad	Method-1	**0.0**	**0.0**	-	-	Chap.21	Investment (Excluded)
	Method-2	**0.0**	0.0	6,834.17	0.00	Chap.61	Routine Maintenance
	Method-3	**0.0**	0.0	70,000.00	0.00		Periodic Maintenance
Rank-2: Very poor	Method-1	**20.0**	10.0	5,151.27	51,512.72	Chap.61	Routine Maintenance
	Method-2	**0.0**	0.0	70,000.00	0.00		Periodic Maintenance
Rank-3: Poor	Method-1	**49.9**	24.9	3,526.07	87,799.24	Chap.61	Routine Maintenance
	Method-2	**0.0**	0.0	70,000.00	0.00		Periodic Maintenance
Rank-4: Fair		**20.0**	10.0	1,395.28	13,952.81	Chap.61	Routine Maintenance
Rank-5: Good		**10.1**	5.0	1,395.28	6,976.40		
Total:		100	49.9		**160,241.16**	(Chap.61)	



(Distance)*(Unit cost) = (Cost)

Unit costs defined above are applied here.

8.6.4 Cost Estimation for Off-carriageway/ Structures/ Road Furniture

Maintenance costs for 1) off-carriageway, 2) structures, and 3) road furniture have been estimated as shown in Table-33, complying with the standardized unit cost for 1-digit roads specified in Table-26. The standard maintenance methods and specifications have been defined digit-class by digit-class, referring to the past projects' information.

Table-33 Cost Estimate for Off-carriageway/ Structures/ Road Furniture

Category	Code	Work Type	Unit	Quanity	Unit Price ($/unit)	Cost ($ per 49.9km)	Unit Cost ($/km)
Off-carriage way	1200	Grading shoulders	km	10.0	365.9	3,659.04	700.00
	1201-2	Adding gravel	m3	2,495	7.8	19,340.49	
	2100	Cleaning channels by labor	m	4,990	0.5	2,312.19	
	2110	Cleaning channels by machine	m	4,990	1.2	6,145.42	
	4150	Vegetation control (shrub, plant and tree)	km	49.9	70.0	3,495.42	
Structures	3100	Cleaning culvert (transversal)	place	75.0	24.6	1,848.63	108.00
	3110	Cleaning culvert (longitudinal)	m	1,497	1.4	2,057.69	
	3200	Minor bridge repair (cleaning, painting)	man/h	250.0	6.1	1,525.09	
Road Furniture	5230	Traffic sign repair	pole	25.0	130.7	3,266.92	236.00
	6100	Cleaning and painting safety poles	pole	598.8	11.8	7,066.72	
	7100	Cleaning and paiting kilometer posts	pole	50.0	29.1	1,455.33	
					Total:	52,172.93	1,044.00

8.6.5 Preparation of Budget Request Forms

The procedure for preparation of the budget request form has been summarized with the following 4 steps. The road list needs to be updated with the cost estimate information.

1) Clarification of the Target Road Information

(1)	Road Name	RN1 (Phnom Penh)
(2)	Road Length (km)	49.9
(3)	Pavement Type	AC
(4)	The number of Lanes	2
(5)	Carriageway width (m)	7.0
(6)	Road Class	1-digit roads

Note: - Standard carriageway width is 7.0m (2 lanes).
- "Carriageway width" is set by 2 lanes even if it has 4 lanes.

2) Cost Estimation for Maintenance of Carriageways

Code	Maintenance Work	Unit	Quantity	Price ($)	Cost ($)
1131	Join and Crack Filling	m2	12,595.58	3.63	45,721.94
1150	Shape Correction	m2	12,789.65	8.17	104,491.47
1100	Pothole Repair by AC	m2	858.54	11.68	10,027.75
-	Overlay with AC	m2	0.00	10.00	0.00
				Total: ($)	160,241.16

($/km) Unit cost 3,211

3) Cost Estimation for Off-carriageway/ Structures/ Road Furniture

Category	Code	Work Type	Unit	Quanity	Unit Price ($/unit)	Cost ($ per 49.9km)	Unit Cost ($/km)
Off-carriage way	1200	Grading shoulders	km	10.0	365.9	3,659.04	700.00
	1201-2	Adding gravel	m3	2,495	7.8	19,340.49	
	2100	Cleaning channels by labor	m	4,990	0.5	2,312.19	
	2110	Cleaning channels by machine	m	4,990	1.2	6,145.42	
	4150	Vegetation control (shrub, plant and tree)	km	49.9	70.0	3,495.42	
Structures	3100	Cleaning culvert (transversal)	place	75.0	24.6	1,848.63	108.00
	3110	Cleaning culvert (longitudinal)	m	1,497	1.4	2,057.69	
	3200	Minor bridge repair (cleaning, painting)	man/h	250.0	6.1	1,525.09	
Road Furniture	5230	Traffic sign repair	pole	25.0	130.7	3,266.92	236.00
	6100	Cleaning and painting safety poles	pole	598.8	11.8	7,066.72	
	7100	Cleaning and paiting kilometer posts	pole	50.0	29.1	1,455.33	
					Total:	52,172.93	1,044.00

4) Preparation of Budget Request Forms with the Above Costs

Code	Work Type	Unit	Quanity	Unit Price ($/unit)	Cost ($)
1131	Join and Crack Filling	m2	12,595.58	3.63	45,721.94
1150	Shape Correction	m2	12,789.65	8.17	104,491.47
1100	Pothole Repair by AC	m2	858.54	11.68	10,027.75
-	Overlay with AC		0.00	10.00	0.00
1200	Grading shoulders	km	10.00	365.90	3,659.04
1201-2	Adding gravel	m3	2,495.00	7.75	19,340.49
2100	Cleaning channels by labor	m	4,990.00	0.46	2,312.19
2110	Cleaning channels by machine	m	4,990.00	1.23	6,145.42
4150	Vegetation control (shrub, plant and tree)	km	49.90	70.05	3,495.42
3100	Cleaning culvert (transversal)	place	75.00	24.65	1,848.63
3110	Cleaning culvert (longitudinal)	m	1,497.00	1.37	2,057.69
3200	Minor bridge repair (cleaning, painting)	man/h	250.00	6.10	1,525.09
5230	Traffic sign repair	pole	25.00	130.68	3,266.92
6100	Cleaning and painting safety poles	pole	598.80	11.80	7,066.72
7100	Cleaning and paiting kilometer posts	pole	50.00	29.11	1,455.33
				Toatal: ($)	212,414.09

Appendix:
Dynamic Response Intelligent Monitoring System (DRIMS)

Appendix: Dynamic Response Intelligent Monitoring System (DRIMS)

CHAPTER 1 Application of DRIMS for IRI Measurement

1.1 Equipment for IRI Measurement

Currently, a variety of IRI measurement equipment is available. As shown Table-A1, according to World Bank (WB) criteria, the IRI measurement equipment is classified into 4 ranks. Among a number of the equipment types, Dynamic Response Intelligent Monitoring System (DRIMS), rated as "Class III (vibration-based IRI measurement)" by WB criteria, is recommended for new road maintenance system using IRI for its several advantageous features.

Table-A1 Classification of Roughness (IRI) Measuring Equipment

(Source: Data Collection Technologies for Road Management Version 2.0 – February 2007, WB)

CLASS	EQUIPMENT
Class I Precision profiles	**Laser profilers:** Non-contact lightweight profiling devices and portable laser profilers **Manually operated devices:** e.g. TRL beam, Face Dipstick/ROMDAS Z-250, ARRB Walking Profiler
Class II Other profilometer methods	APL profilometer, profilographs (e.g., California, Rainhart), optical profilers, and inertial profilers (GMR)
DRIMS **Class III** IRI estimates from correlation equations	Roadmaster, ROMDAS, Roughometer, TRL Bump Integrator, rolling straightedge.
Class IV Subjective ratings/uncalibrated measures	Key code rating systems, visual inspection, ride over section

1.2 Main Features of DRIMS

As illustrated in Figure-A1, application of DRIMS is comprehensively rational, compared to other IRI measurement equipment. Major features of DRIMS are;

1) compact & easy installation without vehicle modification,
2) inexpensive,
3) needs of small amount of energy (car-battery-operated),
4) available for any types of cars, and
5) accurate IRI estimation within driving speed range of 30 to 110 km/h.

Even though the accuracy of DRIMS, which is one of vibration-based IRI measurement devices, is not equivalent to that of laser profilers (Class I by WB criteria), DRIMS has more advantages that cover its weakness. Cost-effectiveness and user-friendly interface are the most important issues to be considered for sustainability of its application. The above 5 features of DRIMS enables us to achieve optimal performance of IRI application in routine road maintenance.

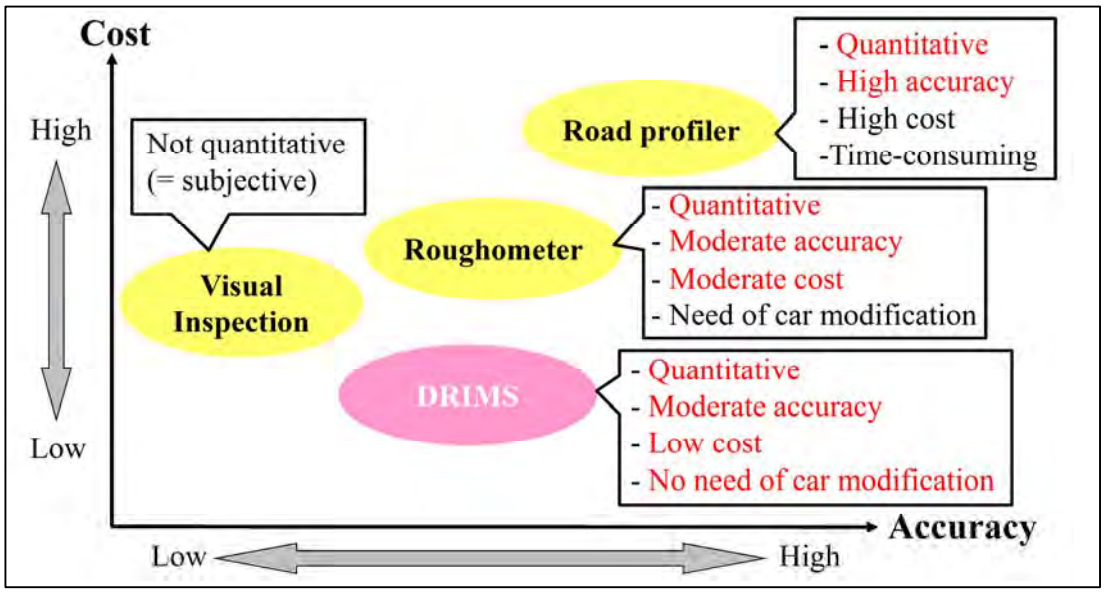


Figure-A1 Comparison of Roughness Inspection Equipment

1.3 Outline of DRIMS

Figure-A2 illustrates brief explanation on IRI measurement mechanism of DRIMS and installation image of DRIMS equipment into ordinary cars. As shown in the left figure, vibration data obtained by an accelerometer above one of the rear tires is converted into IRI values. Also, as shown in the right figure, DRIMS is very compact and can be easily installed into ordinary cars without any modification of car shapes.

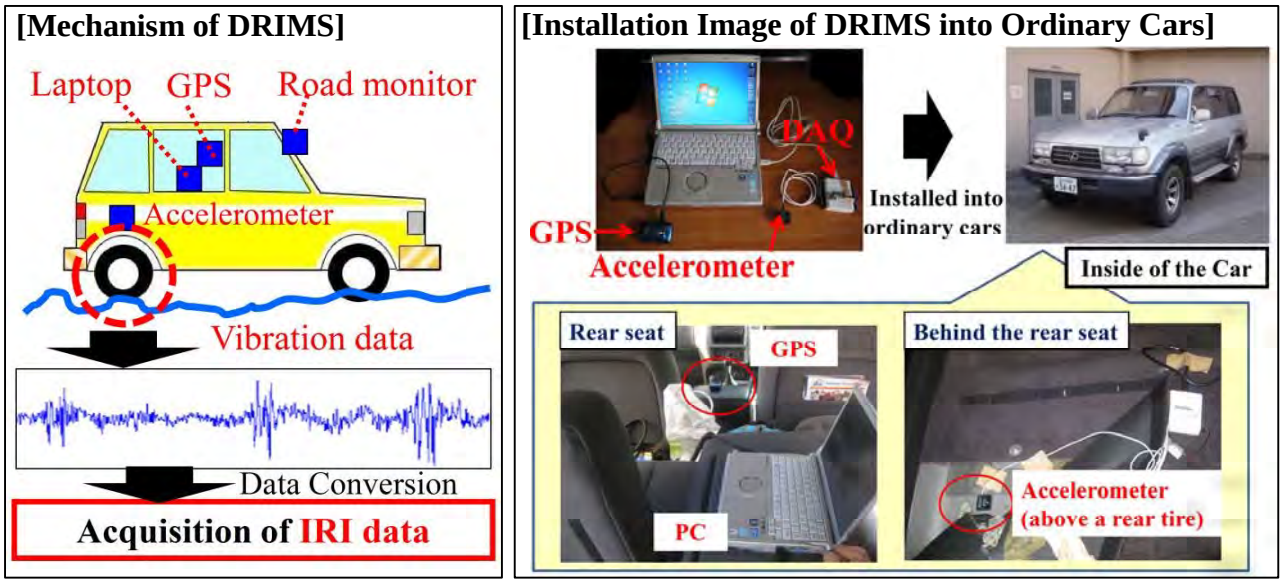


Figure-A2 Mechanism and Installation Image of DRIMS

1.4 Basic Composition of DRIMS

One set of DRIMS is composed of the following 6 items shown in Table-A2. Basically, items No.1-No.5 are always installed into inspection cars as shown in Figure-A2. Item No.6, Humps, is used only during hump calibration activity. Additionally, road monitoring device (recorder) can be utilized with DRIMS for

more visual output.

Table-A2 Basic Composition of DRIMS

No.	Items	Photo	Description
1	Laptop PC		Acquisition of vibration data & conversion of the vibration data into IRI values
2	GPS		Recording of locations during measurement
3	Accelerometer		Measurement of vehicles' vibration data
4	DAQ (Data Acquisition Module)		For transferring the data from accelerometer to computer
5	Tape	 	One-sided tape: fixing of Accelerometer Two-sided tape: fixing of DAQ
6	Humps		Applied to hump calibration
7	Color cone		Applied to hump calibration (to be installed at start point)
Additional Device (Option)			
*A	Road monitoring device (Road condition recorder)	 [SD-Card] 	Recording of road conditions (The data is to be saved in SD-Card.)
*B	DC-AC Inverter		Power source for the laptop PC connected to a cigarette lighter socket of the vehicle

1.5 Standard Performance of DRIMS

Standard performance of DRIMS is shown in Table-A3. It should be noted that IRI values can't be measured under 30km/h by DRIMS.

Table-A3 Standard Performance of DRIMS

Item	Standard Performance
Reliability of IRI	Less than 0.5mm/m
Accuracy of IRI	Error range: IRI value of ± 1.0 on good condition roads
Applicable driving speed range	30-110km/h Note: IRI values can't be measured under 30km/h.
Maximum distance for inspection per day	500-1000km/day
IRI calculation time	Less than 10 min for 100km

CHAPTER 2　IRI Measurement Using DRIMS

2.1　Outline of IRI Measurement Using DRIMS

Figure-A3 summarizes the procedure of IRI measurement using DRIMS. In inspection stage, “IRI measurement with DRIMS” and “road monitoring with recording device” are carried out simultaneously. In addition, before or after the inspection, hump calibration shall be conducted prior to analysis stage in which IRI values of inspected roads are calculated with assumptive vehicle properties based on hump calibration result. As the result of the analysis, IRI map (Google Earth format) and IRI data sheet (CSV format) are to be given. Also, movie with GPS locations are separately obtained as an output of the recording device.

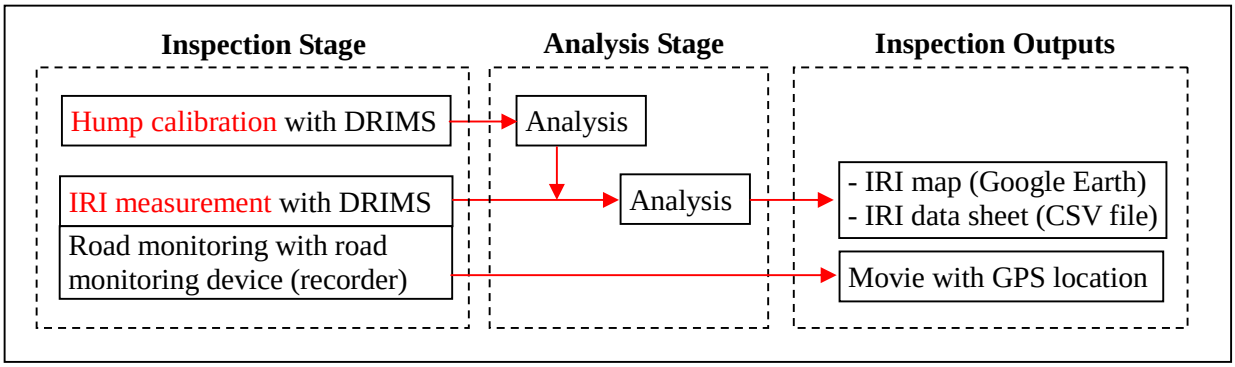


Figure-A3　Outline of IRI Measurement Using DRIMS

2.2　Hump Calibration

2.2.1　Objective of Hump Calibration

Hump calibration shall be conducted in order to adjust different vibration characteristics of inspection vehicles. As shown in Figure-A4, vehicle response (vibration) is quite different, depending on vehicle types. This means, IRI values could be a lot different due to vehicle types. Therefore, vehicle models in IRI-analysis software shall be standardized by hump calibrations in order to maintain consistency of IRI.

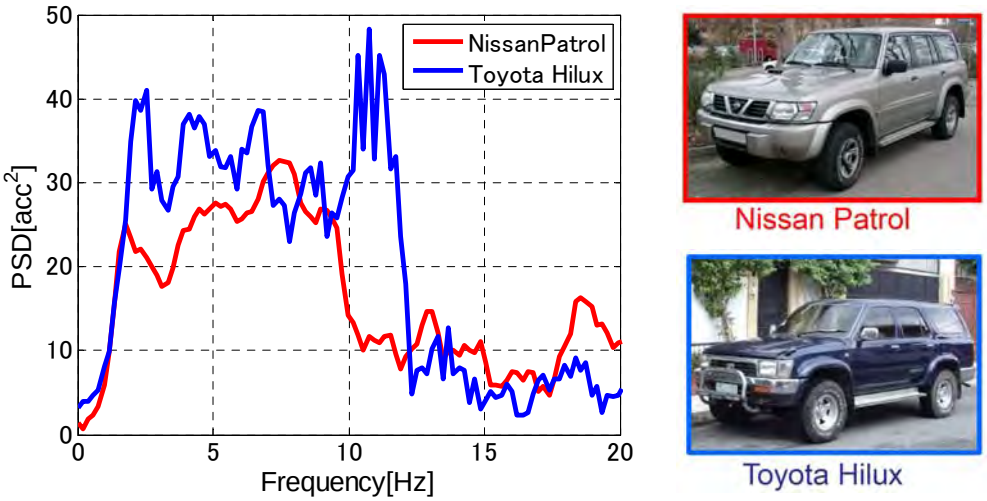


Figure-A4　Comparison of Vehicle Response Difference

2.2.2 Hump Calibration Procedure

Figure-A5 explains the outline of standard hump calibration procedure. Hump calibration requires about 100m flat driving course. Vehicles speed up in the first 20m of the course and maintain constant speed of 20km/h before they get on humps. After passing the humps, the vehicles still maintain 20km/h for 5 seconds and begin to speed down. This process, hump calibration, shall be conducted at least 5 times. It should be noted that the distance indicated in Figure-A5 is a reference, but not a specific rule. Small difference of the distance does not affect the calibration results so much as long as the constant driving speed of 20km/h is maintained about 5 seconds before and after vehicles get of the humps. It also should be noted that the number of passengers shall be the same as that for IRI measurement.

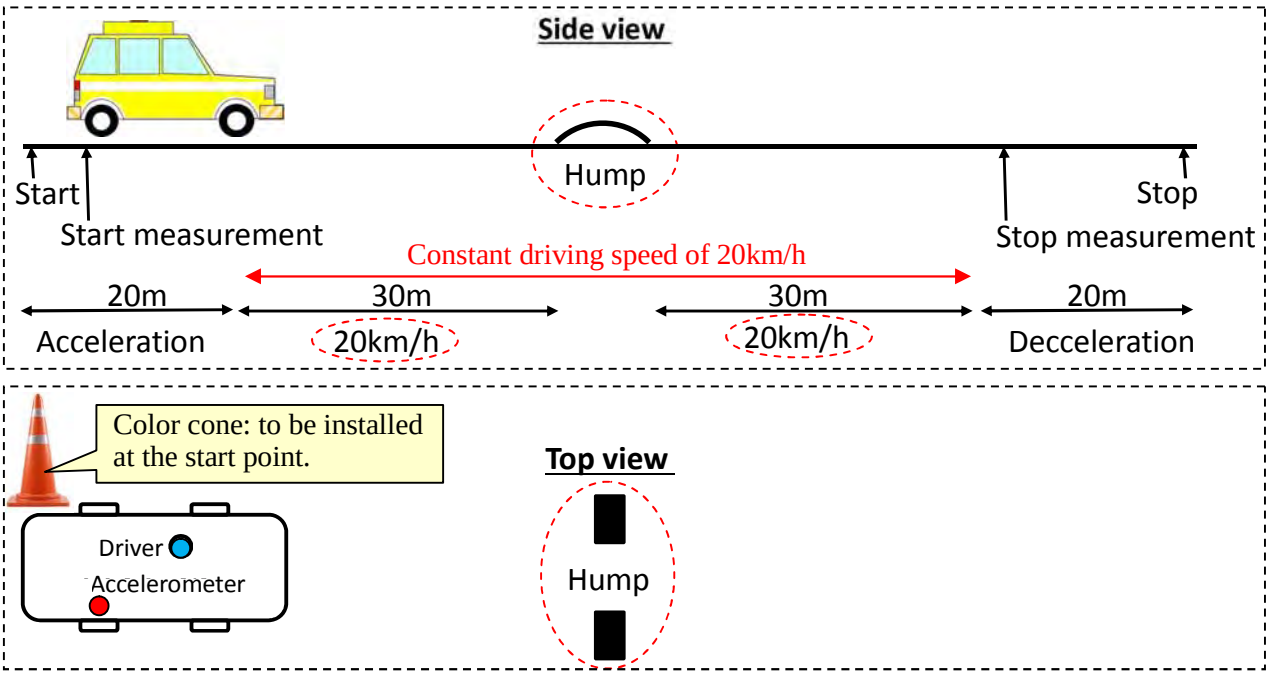


Figure-A5 Standard Hump Calibration Procedure

2.2.3 Effect of Hump Calibration

Figure-A6 shows effect of hump calibration on IRI value calculation; IRI values of 2 different type vehicles are similar (adjusted by hump calibration).

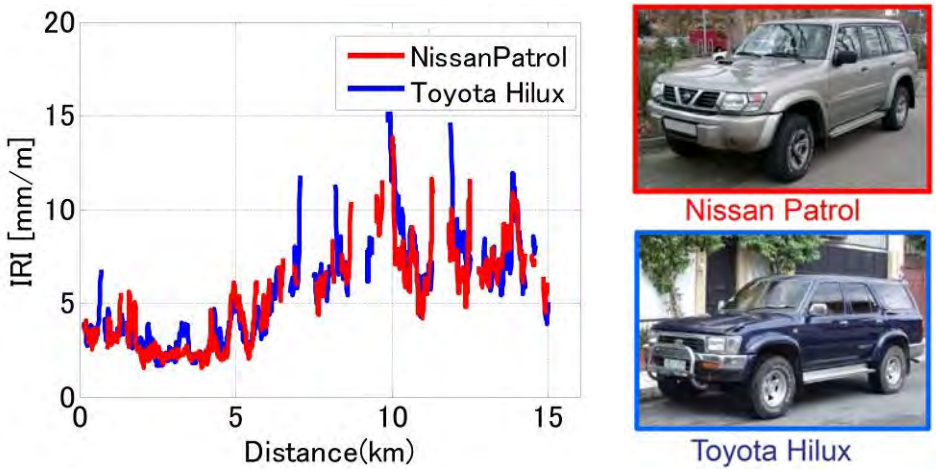


Figure-A6 Comparison of IRI Values after Hump Calibration

2.3 Outputs of IRI Measurement Using DRIMS

2.3.1 Outline

As already explained in Figure-A3, the following 3 outputs are given by inspection using DRIMS.

1) IRI map (Google Earth file)
2) IRI data sheet (CSV file)
3) Movie with GPS location

2.3.2 IRI Maps

(1) IRI Map

As shown in Figure-A7, road conditions are indicated by 5 different colors on IRI maps, depending on their IRI ranges. The maps are prepared in Google Earth file format.

Figure-A7 IRI Map

(2) Location of Identified Major Findings

In addition to IRI maps, location of major defects can be indicated on satellite maps as shown in Figure-A8. Also, location of bridge expansion joints can be displayed if they are checked during inspections.

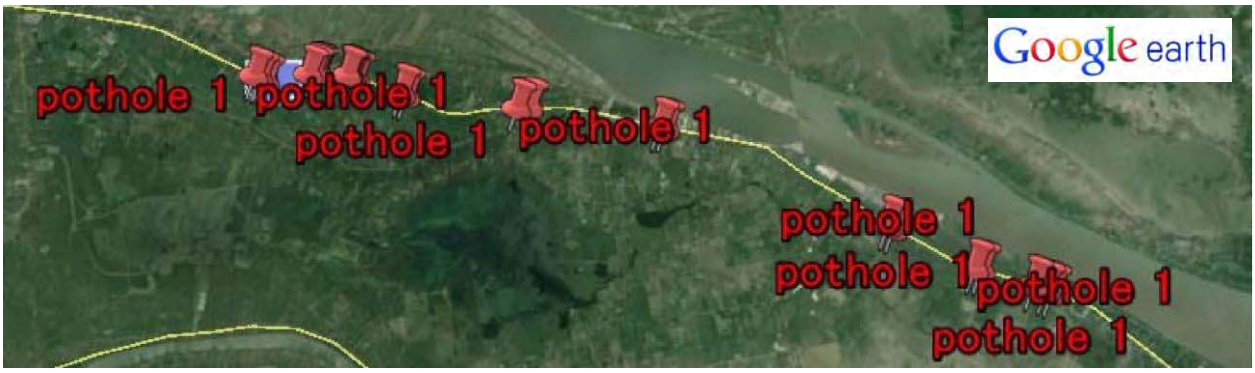


Figure-A8 Location Map for Major Defects

2.3.3 IRI Data Sheet

Basic information acquired during inspection is given as IRI data sheet in CSV file format as shown in Figure-A9. The data sheets include time of recording, distance (location of measurement), IRI values (at 10m interval), GPS information, driving speed, number of identified defects, and number of bridge expansion joints.

DRIMS	distance	IRI	latitude	longitude	altitude	speed	Pothole	Joint
7/24/2015 3:05:30 AM	0	7.68909	11.53151	104.935	14.8	17.72911	0	0
7/24/2015 3:05:45 AM	10	7.68909	11.53156	104.9351	14.1099	17.72911	0	0
7/24/2015 3:05:48 AM	20	7.68909	11.53159	104.9352	15.0071	17.72911	0	0
7/24/2015 3:05:50 AM	30	7.68909	11.53162	104.9353	15.4388	17.72911	0	0
7/24/2015 3:05:51 AM	40	7.68909	11.53165	104.9354	15.5284	17.72911	0	0
7/24/2015 3:05:53 AM	50	7.68909	11.53168	104.9355	15.3843	17.72911	0	0
7/24/2015 3:05:54 AM	60	7.68909	11.5317	104.9355	15.0425	17.72911	0	0
7/24/2015 3:05:56 AM	70	7.68909	11.53172	104.9356	14.5891	17.72911	0	0
7/24/2015 3:05:57 AM	80	7.68909	11.53173	104.9357	14.57	17.72911	0	0
7/24/2015 3:05:59 AM	90	7.68909	11.53175	104.9358	14.5411	17.72911	1	0
7/24/2015 3:06:01 AM	100	7.68909	11.53176	104.9359	14.3648	17.72911	0	0
7/24/2015 3:06:03 AM	110	6.6612	11.53177	104.936	14.4737	18.33262	0	0
7/24/2015 3:06:10 AM	120	6.71969	11.53177	104.9361	14.4	18.44898	0	0

Figure-A9 IRI Data Sheet

2.3.4 Movies with GPS Locations

Recorded movies with GPS locations can be used as road monitoring system. As illustrated in Figure-A10, the road monitoring system is combination of movies, GPS location maps, driving speed (time history based), IRI values (time history based), and speed meter & odometer. The system is very useful for reviewing the inspections.

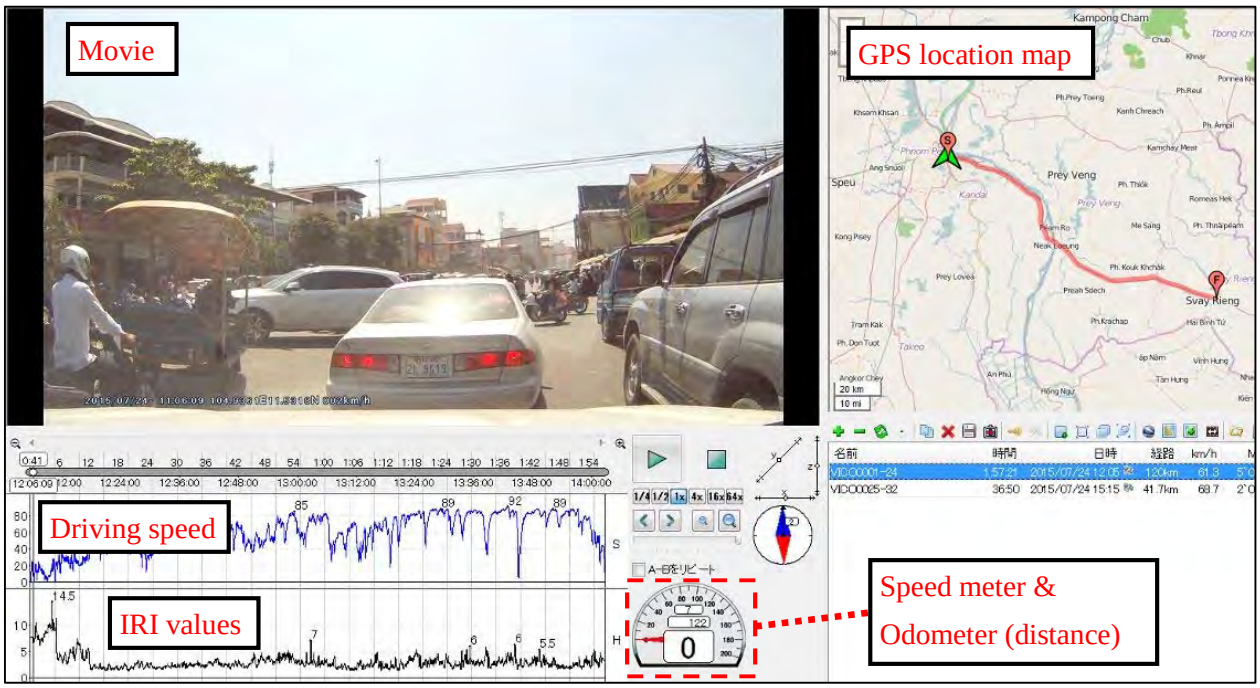
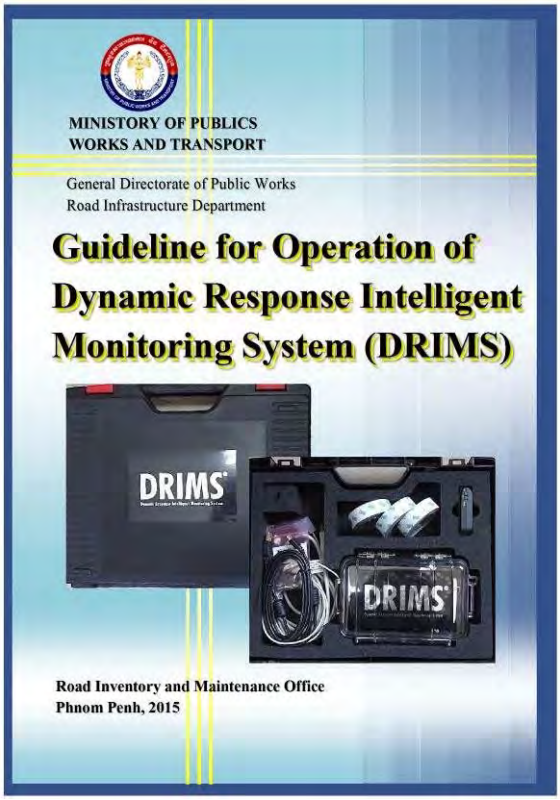


Figure-A10 Road Monitoring System

2.3.5 Guideline for DRIMS Operation

The details of DRIMS operation is explained in “Guideline for Operation of Dynamic Response Intelligent Monitoring System (DRIMS)” shown in
Figure-A11. The guideline is composed of 9 chapters that describe whole entire procedure of DRIMS application to road maintenance management.



Guideline for Operation of Dynamic Response Intelligent Monitoring System (DRIMS)

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Figure-A11 Guideline for Operation of Dynamic Response Intelligent Monitoring System (DRIMS)

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