**MINISTRY OF PUBLIC WORKS AND TRANSPORT**
**THE KINGDOM OF CAMBODIA**

# THE PROJECT

# FOR

# STUDY ON THE IMPROVEMENT OF EXISTING BRIDGES

# IN

# THE KINGDOM OF CAMBODIA

# FINAL REPORT

# VOLUME I
# EXECTIVE SUMMARY

**March 2013**


**JAPAN INTERNATIONAL COOPERATION AGENCY**

**CHODAI CO., LTD.**
**ORIENTAL CONSULTANTS CO.,LTD.**


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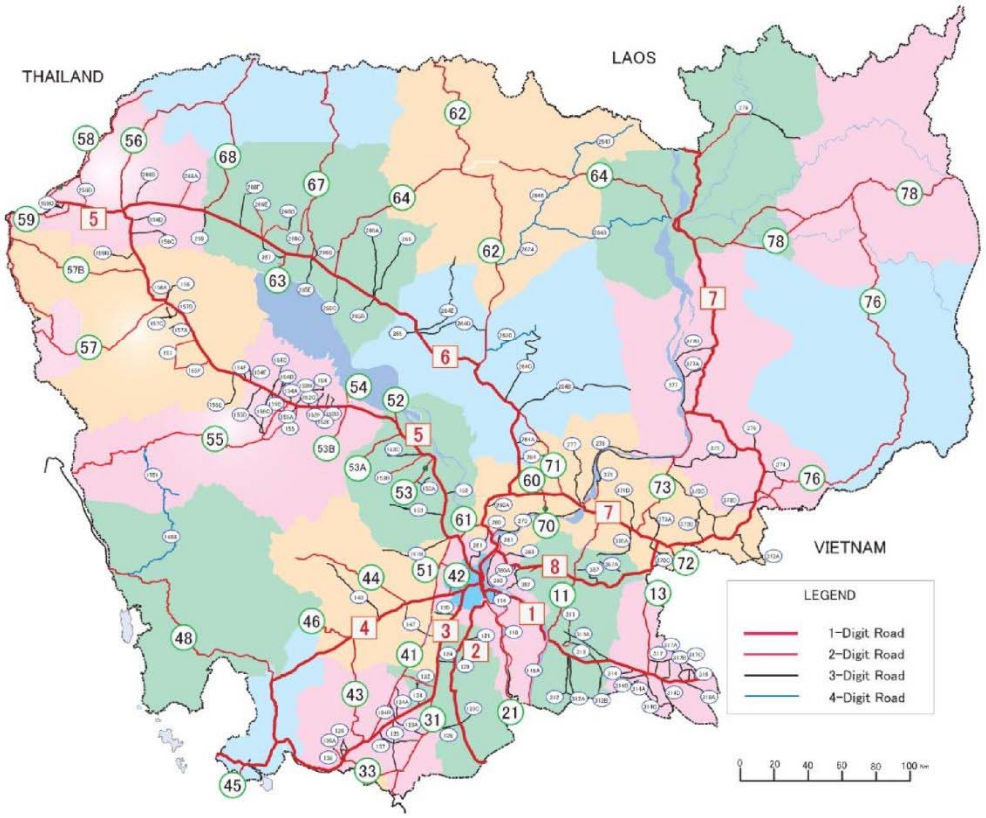
| JR |
| 13-047 |

The following foreign exchange rates are applied in the Study:

USD 1.00 = 80.41 JPY (as of 2012)

USD 1.00 = 4,127.27 KHR (as of 2012) *KHR: (Cambodian Riel)

# LOCATION MAP OF THE STUDY




## NUMBER OF ROADS AND BRIDGES FOR THE STUDY

| | ROAD | BRIDGE |
|---|---|---|
| 2-DIGIT NATIONAL ROAD | 37 | 668 |
| 3-DIGIT PROVINCIAL ROAD | 124 | 505 |
| 4-DIGIT PROVINCIAL ROAD | 7 | 32 |
| TOTAL | 168 | 1205 |

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LIST OF ABBREVIATIONS

| | |
|---|---|
| ADB | Asian Development Bank |
| AHP | Analytic Hierarchy Process |
| ASEAN | Accociation of Southeast Asian Nations |
| CDC | Council for Development of Cambodia |
| B/C | Benefit Cost Ratio |
| BMS | Bridge Management System |
| DBST | Double Bituminous Surface Treatment |
| DPWT | Department of Public Works and Transport |
| EIA | Environmental Impact Assessment |
| EIRR | Economic Internal Rate of Return |
| GPS | Global Positioning System |
| GMS | Great Mekong Sub-Region |
| GIS | Geographic Information System |
| HEC | Heavy Equipment Center |
| HWL | High Water Level |
| HV | Heavy Vehicle |
| IEE | Initial Environmental Examination |
| IEIA | Initial Environmental Impact Assessment |
| ICD | International Cooperation Department |
| IMC | Inter-Ministerial Committee |
| IRC | Inter-ministerial Resettlement Committee |
| JICA | Japan International Cooperation Agency |
| MPWT | Ministry of Public Works and Transport |
| MEF | Ministry of Economy and Finance |
| MOE | Ministry of Environment |
| MRD | Ministry of Rural Development |
| MAFF | Ministry of Agriculture, Forestry and Fisheries |
| MOJ | Ministry of Justice |
| MLMUPC | Ministry of Land Management Urban Planning and Construction |
| MINE | Ministry of Industry, Mines and Energy |
| MC | Motorcycle |
| NR | National Road |
| NPV | Net Present Value |
| LV | Light Vehicle |
| IMF | International Monetary Fund |
| PR | Provincial Road |
| PWRC | Public Works Research Center |
| PK | Kilometer Post of on the road |
| RAMP | Road Asset Management Project |
| RID | Road Infrastructure Department |
| RGC | Royal Government of Cambodia |
| ROW | Right of Way |
| SPIED | Sub-National Public Infrastructure and Engineering Department |
| SEZ | Special Economic Zones |
| TTC | Travel Time Cost |
| VOC | Vehicle Operation Cost |
| WB | World Bank |

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# 1. OUTLINE OF THE PROJECT

## 1.1 Background of the Project

The Royal Government of the Kingdom of Cambodia (hereinafter referred to as the Cambodia) has been trying to rehabilitate the roads and bridges by its own funds and the funds from foreign donors. There are many temporary bridges still remain on national and provincial roads and they are not inspected nor maintained well. Damaged temporary bridges are often left unrepaired for a long time and they sometimes collapsed accidentally or are damaged due to heavy truck loading or natural disaster including the flooding of 2011.

With this background, the Cambodia requested Japanese Government to carry out The Study on the Improvement of Existing Bridges (hereinafter referred to as the Study) for the replacement of the existing temporary bridges on 2-, 3- and some 4-digit roads (hereinafter referred to as the target roads) to permanent bridges and preparation for capacity development project for bridge maintenance. According to the request from the Cambodia, JICA dispatched the Study Team.

## 1.2 Objective of the Project

The project content two packages including plan for bridge replacement (Package A) and capacity development of bridge maintenance (Package B). Objective of the project with each package are as follows:.

### (1) Plan for bridge replacement (Package A)

1) Investigate the inventory of bridges on the target roads and determine the target bridges which should be replaced with permanent bridges.
2) Carry out site survey and inspect bridge conditions including the effects of the flooding of 2011.
3) Establish a database for the target bridges
4) Investigate environmental and social conditions around the bridges.
5) Survey the traffic volume on the target roads.
6) Study the priority of the target roads.
7) Propose the standard of bridge and structure for the replacement of target bridges and estimate their costs.
8) Recommend the priority of bridges to be replaced on the target roads.

**(2) Capacity development of bridge maintenance (Package B)**

1) Review the past programs / projects for bridge maintenance assisted by donor agencies and analyse the present issues and problems to improve the capacity for bridge maintenance in the MPWT.
2) Analyze the present system /database for bridge maintenance in the Cambodia
3) Recommend the programs/ projects to enhance the capacity for bridge maintenance in the MPWT.

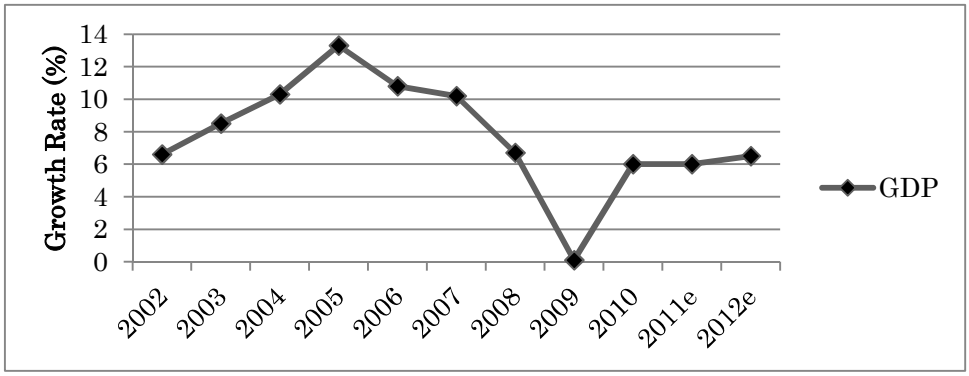
**(3) Study Area**

The study area is shown in the "Location Map"

## 1.3 Socio-Economic Conditions

**(1) Economic Growth**

The economy of Cambodia maintained high growth of more than 10% per annum for four consecutive years between 2004 and 2007 as shown in Figure 1-1. According to the forecast by the Ministry of Economy and Finance (hereinafter referred to as the MEF), the growth rates are estimated to be sustained between 6.0% and 6.5% in 2011 and 2012.




Source: Ministry of Economy and Finance

**Figure 1-1 GDP Annual Growth Rate**

**(2) Government Finance**

According to the data of national revenue and expenditure as shown in Table 1-1, domestic revenue increased by 7% per year on average rate between 2008 and 2011.

**Table 1-1 National Revenue and Expenditure (Billion Riel)**

| State Budget | 2008 | 2009 | 2010 | 2011 | 2012e |
|---|---|---|---|---|---|
| **Domestic Revenue** | | | | | |
| Current Revenue | 5,213.08 | 4,855.98 | 5,738.77 | 6,368.28 | 7,300.66 |
| Tax Revenue | 4,429.97 | 4,155.19 | 4,691.96 | 5,304.92 | 6,280.38 |
| **Domestic Tax Revenue** | 3,249.93 | 3,090.91 | 3,533.64 | **4,098.71** | 4,919.28 |
| Taxes on international Trade | 1,180.04 | 1,064.28 | 1,158.32 | 1,206.21 | 1,361.10 |
| Non Tax Revenue | 783.11 | 700.79 | 1,046.81 | 1,063.36 | 1,020.27 |
| Property Income | 67.16 | 64.54 | 181.93 | 63.87 | 111.75 |
| Sale of Goods and Services | 427.32 | 407.95 | 452.97 | 596.14 | 585.72 |
| Other Non Tax | 288.63 | 228.30 | 411.91 | 403.35 | 322.81 |
| Capital Revenue | 79.21 | 29.28 | 129.92 | 76.54 | 80.00 |
| Total | **5,292.29** | **4,885.26** | **5,868.69** | **6,444.82** | **7,380.66** |
| **Budget Expenditure** | | | | | |
| Current Expenditure | 3,774.12 | 4,439.69 | 4,792.33 | 5,784.31 | 6,330.66 |
| Wage | 1,437.67 | 2,011.62 | 2,065.88 | 2,232.97 | 2,672.75 |
| **Non Wage** | 2,336.45 | 2,428.07 | 2,726.45 | **3,551.34** | 3,657.91 |
| Capital | 2,654.48 | 2,896.46 | 4,436.59 | 4,746.37 | 4,187.33 |
| Domestic Financing | 711.31 | 1,019.16 | 990.49 | 1,343.68 | 1,327.33 |
| External Assistance (Project) | 1,943.17 | 1,877.30 | 3,446.10 | 3,402.69 | 2,860.00 |
| Total | **6,428.60** | **7,336.15** | **9,228.92** | **10,530.68** | **10,517.98** |

Source: Ministry of Economy and Finance, Monthly Bulletin Statistics

The budget financing by the difference of revenue and expenditure has increased by 55% as an average annual growth rate as shown in Table 1-2. The financing from by the foreign and domestic financing in 2011 reached 3,937.16 billion Riel. The project aid financed by international borrowing and foreign assistance was 3,398.38 billion Riel accounting for 86 % of the financing in 2011.The 54% share of debt and related liabilities is a larger amount than the grant in project aid.

**Table 1-2 Deficit Financing (Billion Riel)**

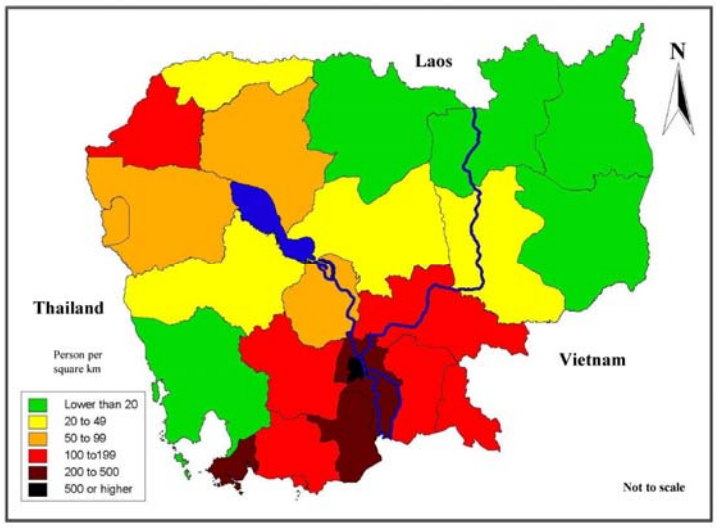
| Financing | 2008 | 2009 | 2010 | 2011 | 2012e |
|---|---|---|---|---|---|
| Foreign Financing | 2,424.40 | 1,926.34 | 3,356.33 | 3,456.70 | 2,630.00 |
| Budget Support | **324.87** | 272.71 | 166.28 | **222.02** | 20.00 |
| Project Aid | 2,200.64 | 1,766.17 | 3,330.50 | **3,398.38** | 2,860.00 |
| Grant | 1,167.82 | 900.00 | 2,219.93 | 1,580.96 | 1,600.00 |
| Debt and related liabilities | 775.36 | 977.30 | 1,226.17 | **1,821.73** | 1,260.00 |
| Pending | 257.46 | -111.13 | -115.60 | -4.31 | |
| Amortization on External Debts | -101.11 | -112.54 | -140.45 | -163.70 | -250.00 |
| Domestic Financing | -1377.52 | 686.59 | 1131.81 | 480.46 | 1063.69 |
| Outstanding Operations | 173.08 | 86.68 | -840.32 | | |
| Total | **1,219.96** | **2,699.61** | **3,647.82** | **3,937.16** | **3,137.32** |

Source: Ministry of Economy and Finance, Monthly Bulletin Statistics

### (3) Population

Cambodia's population was 13.4 million in 2008 and its annual population growth rate of 1.54 % was higher than that of Southeast Asia as a whole. The rates vary from province to province depending on the interaction of fertility, mortality and migration factors. Kampong

Cham continues to be the biggest province in terms of population, although it registered a very low growth rate. The population density as a whole increased from 64 to 75 persons/ square kilometre between1998 and 2008. The population density by each province is shown in Figure 1-2.




Source: Ministry of Planning, NIS, General Population Census 2008

**Figure 1-2 Population Density by Province**

### (4) National Development Plans

The Cambodia has prepared the policies for the further rehabilitation and construction of transport infrastructure in the National Strategic Development Plan 2009-2013(NSDP).

The plan stated that "Transport network is a prime mover of economic growth. The transport network linking all parts of the country makes it a cohesive economic body, and helps to integrate the Cambodian economy into the region and the world. The Cambodia has so far almost completed the rehabilitation and reconstruction of important national roads. The Cambodia will continue to give high priority to the rehabilitation and reconstruction of multimodal transport network connecting all parts of the country, and with neighbouring countries. This will enable provision of convenient, stable, safe, economically efficient, lower cost transportation and logistics services network, aiming at trade facilitation, tourism promotion, rural development, regional and global economic integration as well as national defence." The road sector of the MPWT has committed to carry out the following main activities for the implementation of prioritized policies.

1) Continued strengthening management of road network
2) Continued the construction of the main national roads for the integration of all locations in the country and the region
3) Collaboration with the Ministry of Rural Development (MRD) and city authorities to ensure that the road network is consistently organized.

### (5) Road Development Strategies

The MPWT published the sector plan with the Infrastructure and Regional Integration Technical Working Group (IRITWG) by a prioritized policies of the NSDP. The plan stated the six strategies and described the detailed activities of planning.

**Strategy I: Strengthen and improve the multi growth poles development**

Future project:

1) Upgrade road and try to enlarge them to 4 lanes to connect to potential development poles
2) Improve the road network in development pole
3) Construct bypass and viaduct to solve traffic congestion at development poles
4) Construct express way Phnom Penh-Sihanouk Ville
5) Construct high way Phnom Penh – Chrey Thom
6) Construct express way Phnom Penh – Siem Reap – Poi pet
7) Construct bypass at Siem Reap, Battambang and Kampong Chhnang
8) Construct ring road of Phnom Penh

**Strategy II: Strengthen and improve road network to serve important social economic development region**

1) Road way width of NR 4 and NR 1is enlarged to 4 lanes
2) Construct second Neak Loeung Bridge
3) Prepare plan and develop road network connecting NR 4 and NR 1
4) Improve quality and traffic safety of road at economic development corridor.

**Strategy III: Push the development of tourism**

Enhance road in tourist area in order to offer convenient, good environment, create opportunity to public Establish administrative office at international gates and enhance the connecting road to offer convenience to tourists,

**Strategy IV: National and regional integration**

1) Construct and upgrade 1-, 2-, 3-digit and in province roads
2) Construct and upgrade district and rural roads

**Strategy V: Develop international corridor**

1) Develop international corridor at Greater Mekong Sub-Region (GMS) International Highway
2) Strengthen the function of 1-digit roads and enhance 2-digit roads that defined to 3) be the GMS highway

3) Construct nation-wide road connecting to all international gates:

Vietnam: NR 33, NR 2, NR 21, NR 1, NR 8, NR72, NR74, PR3762 and NR78

Lao: NR7

Thailand: NR62, NR 64, NR 66, NR 5, NR 59, NR 57, NR 55 and NR 58

Others: NR 4 (through Sihanouk Ville seaport)

**Strategy VI: Praise the development of social economy at rural and along border in order to reduce poverty**

1) Strengthen 2-, 3-digit, province and district roads connecting to rural area and road along border that have high potential for agriculture, industry, and tourism
2) Construct road at triangle development (Cambodia, Lao, Vietnam)
3) Construct road at emerald triangle development (Cambodia, Lao, Thai)

### (6) Road Network Condition

The road network in Cambodia consists of 2,117km of 1-digit, 3,146km of 2-digit, 6,441km of provincial road and 33,005km of rural road. The National Road is mostly primary road network linking Phnom Penh to provincial capitals and important centres of population and economic activity. Condition of 1-digit roads is almost maintained by concrete or bituminous pavement including Double Bituminous Surface Treatment (DBST) which has low durability.

Ratio of paved road by the DBST status in 2-digit roads is 30.2%. Ratio of paved road in provincial roads is only 1.7% so that the drivers cannot pass the provincial roads safely during the rainy season. Road network and pavement status are shown in Table1-3.

**Table 1-3 Road network and Pavement Status**

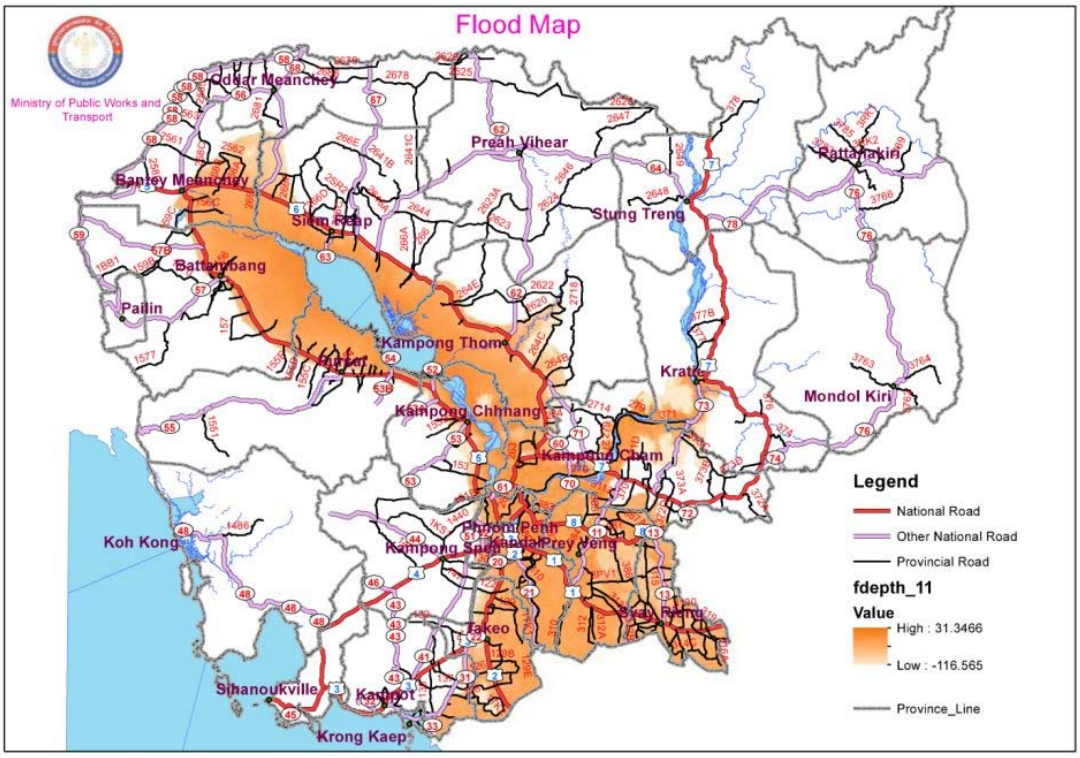
| Road classification | Length (km) | Percentage | Pavement ratio | Pavement status (km) | | | |
|---|---|---|---|---|---|---|---|
| | | | | Earth | Laterite | DBST | Concrete or Asphalt |
| 1-digit roads | 2,117 | 18.1% | 99.1% | 20 | 0 | 1381 | 716 |
| 2-digit roads | 3,146 | 26.9% | 30.2% | 273 | 1923 | 949 | 0 |
| 3- and 4-digit roads | 6,441 | 55.0% | 1.7% | 2437 | 3895 | 101 | 9 |
| Total | 11,704 | 100% | | | | | |

Source: Overview on Transport Infrastructure Sectors, 2010

### (7) Review of Past Flood and Damages

Mekong Delta is very flat and flood develops along the main river systems. When flood occurs, it often covers large areas of Kompong Cham and Prey Veng provinces. The division of the Bassac River at Phnom Penh is an indication of the flatness of the delta and of the complexity of the river system in the Mekong Delta. The flood is attributable to water flow from the Mekong river and also partly to the backwater effect from the Tonle Sap River.

Cambodia is severely affected by the flood between August and October 2011. Transportation assets such as roadway, bridges, culverts, drainage system and agricultural land have been damaged by the flood. The magnitude of the damages extends to 18 provinces as well as Phnom Penh municipality. Damaged infrastructure was surveyed and recorded by the MPWT. The data was used as a primary data to verify the flood area to measure the actual damages. Estimated number of people living in affected areas is 14.8 million and of these an estimated 50 to 60% people are in need of urgent humanitarian assistance. Large parts of the district of 4 provinces including Kampong Cham and Prey Veng provinces are underwater during the month of October. In Seam Reap, flood waters in upstream accumulated in Seam Reap City and other districts located in lowland areas as well as Kampong Cham, Kampong Thom and Prey Veng provinces which were amongst the worst areas affected from October to December 2011. Areas of high damage by the flooding of 2011 are shown in Figure 1-3.




Source: Flood Damage Assessment, 2011 by the MPWT

**Figure 1-3 Flood Map in 2011**

# 2. PRIORITIZATION OF THE TARGET ROADS

Total number of the target roads for the Study is 168 and list of road and roads committed to be developed are shown in Table2-1. Majority of 2-digit and some 3-digit road have been completed or committed to be improved by donors and the Cambodia and funds for improvement of other 3-digit and 4-digit roads are expected as next development.

**Table 2-1 List of Target Road**

| No. | Road Number | Length (Km) | The name of commtted donor | No. | Road Number | Length (Km) | The name of commtted donor | No. | Road Number | Length (Km) | The name of commtted donor |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 11 | 90.28 | Japan, remain 2 Br. | 57 | 140 | 49.50 | Cambodia | 113 | 266F | 24.23 | |
| 2 | 13 | 45.60 | ADB | 58 | 147 | 34.61 | | 114 | 267 | 20.51 | |
| 3 | 21 | 65.56 | China | 59 | 151B | 63.68 | | 115 | 268A | 15.92 | |
| 4 | 31 | 54.81 | Korea | 60 | 152 | 5.27 | | 116 | 268B | 44.68 | |
| 5 | 33 | 52.27 | Korea | 61 | 152D | 6.82 | | 117 | 269 | 12.76 | |
| 6 | 41 | 96.45 | China | 62 | 152E | 7.07 | | 118 | 270 | 59.34 | ADB |
| 7 | 42 | 24.26 | | 63 | 152F | 9.00 | | 119 | 277 | 39.84 | |
| 8 | 43 | 78.88 | China | 64 | 152G | 3.94 | | 120 | 279 | 33.92 | |
| 9 | 44 | 84.84 | China | 65 | 152H | 11.34 | | 121 | 311 | 8.45 | Cambodia |
| 10 | 45 | 9.30 | | 66 | 153 | 40.83 | | 122 | 312 | 28.66 | Cambodia |
| 11 | 46 | 26.99 | | 67 | 153A | 14.49 | | 123 | 312A | 21.17 | |
| 12 | 48 | 161.27 | Korea | 68 | 153B | 24.71 | | 124 | 312B | 22.09 | |
| 13 | 51 | 38.01 | Cambodia | 69 | 153C | 14.30 | | 125 | 313 | 41.22 | |
| 14 | 52 | 8.01 | | 70 | 154 | 26.82 | | 126 | 313A | 28.67 | |
| 15 | 53 | 49.15 | ADB | 71 | 154A | 15.58 | | 127 | 314 | 11.01 | |
| 16 | 53A | 29.75 | | 72 | 154B | 15.58 | | 128 | 314A | 9.60 | |
| 17 | 53B | 22.30 | | 73 | 154C | 10.44 | | 129 | 314B | 14.85 | Cambodia |
| 18 | 54 | 4.87 | | 74 | 154E | 12.00 | | 130 | 314C | 45.88 | |
| 19 | 55 | 185.20 | China | 75 | 154F | 11.25 | | 131 | 314D | 25.67 | |
| 20 | 56 | 113.62 | ADB | 76 | 155 | 38.89 | | 132 | 315 | 61.76 | |
| 21 | 57 | 103.34 | China | 77 | 155A | 13.96 | | 133 | 316A | 14.33 | |
| 22 | 57B | 176.35 | China | 78 | 155B | 10.75 | | 134 | 317 | 8.55 | |
| 23 | 58 | 104.00 | China | 79 | 155C | 26.07 | | 135 | 317A | 22.41 | Cambodia |
| 24 | 59 | 144.27 | China | 80 | 155D | 19.47 | | 136 | 317B | 15.80 | |
| 25 | 60 | 19.94 | | 81 | 155E | 22.47 | | 137 | 317C | 6.92 | |
| 26 | 61 | 16.00 | China | 82 | 155F | 23.40 | | 138 | 319 | 13.19 | |
| 27 | 62 | 242.66 | China | 83 | 156 | 19.35 | | 139 | 370A | 17.18 | |
| 28 | 63 | 14.31 | | 84 | 156A | 15.80 | | 140 | 370C | 25.87 | |
| 29 | 64 | 236.68 | China | 85 | 156C | 22.29 | | 141 | 371 | 89.51 | China |
| 30 | 67 | 133.87 | Cambodia | 86 | 156D | 11.23 | | 142 | 371D | 46.71 | |
| 31 | 68 | 117.68 | ADB | 87 | 157 | 26.78 | | 143 | 372A | 29.07 | |
| 32 | 70 | 13.53 | | 88 | 157A | 8.80 | | 144 | 373A | 23.05 | |
| 33 | 71 | 57.83 | Cambodia | 89 | 157B | 7.99 | | 145 | 373B | 25.39 | |
| 34 | 72 | 13.50 | Cambodia | 90 | 157C | 24.57 | | 146 | 373C | 53.72 | Cambodia |
| 35 | 73 | 92.40 | Request to Japan | 91 | 159B | 62.10 | | 147 | 373D | 27.28 | |
| 36 | 76 | 306.18 | China | 92 | 159D | 20.63 | Cambodia | 148 | 374 | 18.06 | |
| 37 | 78 | 193.96 | China | 93 | 258D | 18.05 | China | 149 | 375 | 45.96 | |
| 38 | 110 | 85.75 | Cambodia | 94 | 260 | 4.24 | Cambodia | 150 | 376 | 9.96 | |
| 39 | 114 | 3.39 | | 95 | 260A | 6.40 | | 151 | 377 | 40.61 | |
| 40 | 118A | 42.53 | Cambodia | 96 | 261 | 24.14 | Cambodia | 152 | 377A | 29.93 | |
| 41 | 121 | 8.85 | | 97 | 264 | 10.85 | | 153 | 377B | 13.44 | |
| 42 | 124 | 10.21 | | 98 | 264A | 15.48 | | 154 | 378 | 79.01 | Cambodia |
| 43 | 126 | 16.39 | | 99 | 264B | 119.26 | | 155 | 380 | 25.80 | Cambodia |
| 44 | 129 | 22.48 | | 100 | 264C | 70.72 | | 156 | 380A | 4.16 | |
| 45 | 129C | 2.21 | | 101 | 264D | 48.43 | Cambodia | 157 | 381 | 10.53 | Cambodia |
| 46 | 130 | 30.82 | | 102 | 264E | 57.32 | Cambodia | 158 | 382 | 13.19 | Cambodia |
| 47 | 132 | 20.81 | | 103 | 265 | 7.56 | | 159 | 383 | 13.68 | Cambodia |
| 48 | 133A | 20.39 | | 104 | 265B | 8.01 | | 160 | 387 | 28.46 | |
| 49 | 134 | 16.31 | | 105 | 265C | 12.74 | | 161 | 387A | 16.49 | |
| 50 | 134A | 20.12 | | 106 | 265E | 11.81 | | 162 | 1488 | 75.00 | China |
| 51 | 134B | 10.46 | | 107 | 266 | 39.39 | | 163 | 1551 | 41.17 | China |
| 52 | 135 | 30.88 | | 108 | 266A | 38.38 | | 164 | 2620 | 29.68 | |
| 53 | 136 | 16.57 | | 109 | 266B | 21.46 | | 165 | 2624 | 78.95 | |
| 54 | 136A | 3.71 | | 110 | 266C | 31.00 | | 166 | 2646 | 41.26 | |
| 55 | 137 | 27.58 | | 111 | 266D | 29.08 | | 167 | 2647 | 65.54 | |
| 56 | 138 | 10.01 | Cambodia | 112 | 266E | 87.29 | | 168 | 2648 | 63.31 | |

Source: Study Team

The replacement of temporary bridges has high priority for improvement of the road network. However, the budget for the bridge replacements is limited due to the budget constraint so that prioritization to determine the order for bridge replacement is essential. As a bridge is a part of roads, a group of bridges on each road among the target roads shall be prioritized. The priority of the bridge replacement will be analysed by Analytic Hierarchy Process (AHP).

The prioritization of bridge replacement will be implemented by the following steps;

1) Set up attributes for the evaluation and intensity of each attribute
2) Prioritization of the target roads and nomination of roads for bridge replacement
3) Prioritization of bridges on the nominated roads

## 2.1 Selection of the Target Roads for Bridge Replacements

### (1) Attribute for Evaluation of Priority of the Target Roads

1. Priority of roads selected through the follow up study on the road network development master plan, 2009 (short-, Medium and long-term)
2. Population along roadside area of the target roads.
3. Traffic volume of the target roads
4. Character of the road i.e. road to the border, road composed of the road network, road to dead end
5. Economic status of the roadside area i.e. agricultural area, industrial area and others.
6. Number of buildings in vicinity of the bridges

### (2) Attribute for Selection of the Target Bridges

1. Maximum high water level
2. Deterioration rate of the bridge
3. Bridge width
4. Type of bridge i.e. wooden, bailey, concrete and steel bridge

## 2.2 Evaluation Method

### (1) The Analytic Hierarchy Process (AHP)

The roads and bridges are prioritized by using the AHP. The weights for the evaluation factors are examined by the pair wise comparison matrix of each attribute.

1) Introduction

The AHP is a priority ordering method for use as a factor in decision making. It is a systematic procedure which uses a matrix of pair wise comparisons to derive relative priority. The steps for setting weight by the AHP are as follows:

Step 1. Determine the attributes used for route priority setting.
Step 2. Compare and evaluate the attributes for relative importance.
Step 3. Set the priorities of the routes by using the weight of attribute and intensity of attributes for the route.

The user must select or establish attributes and determine the scale of relative importance for each attribute. The scale of relative importance is shown in Table 2-2.

.

**Table 2-2 Scale of Relative Importance**

| **Intensity of Relative Importance** | **Definition** | **Explanation** |
|---|---|---|
| 1 | Equal importance | Two activities contribute equally to the objective. |
| 3 | Moderate importance of one over another | Experience and judgment slightly favor one activity over another. |
| 5 | Essential or strong Importance | Experience and judgment slightly favor one activity over another. |
| 7 | Demonstrated Importance | An activity is strongly favored and its dominance is demonstrated in practice. |
| 9 | Extreme importance | The evidence favoring one activity over Another is of the highest possible order of affirmation. |
| 2, 4, 6, 8 | Intermediate values between the two adjacent judgments | When compromise is needed. |
| Reciprocal of above Non-zero numbers | If an activity has one of the above numbers (e.g.3) compared with A second activity, then the second activity has the reciprocal value (i.e.1/3) when compared to the first. | |

2) Steps to Obtain the Weight of the Attribute

a) Define the problem and determine what the decision maker wants to know.
b) Structure the hierarchy from the top (the objectives from a managerial viewpoint) through the intermediate levels (criteria on which subsequent levels depend) to the lower level (which usually a list of candidate bridges being selected by deficiency point method or sufficiency method).
c) Construct a set of pair wise comparison matrices for each of the lower levels- one matrix for each element in the level immediately above. Compare to each other, the elements in the lower level based on their effects on the governing elements above.
d) There are n(n-1)/2 judgments required to develop the matrix.
e) Weight of each attribute is obtained by normalization of the Eigen value.

## 2.3 Results of the Analysis

### (1) Weight of each attribute

Weights for setting the priority of the target roads are examined by the six Cambodian counterparts with same method mentioned above and the weights for each attribute are evaluated as shown in Table 2-3.

**Table 2-3 Weight evaluated by the Cambodian Counterparts**

| Attribute for prioritization | Weight |
|---|---|
| A: Priority road determined by the master plan (Short, Medium, Long term) | 0.352 |
| B: Population along the road | 0.062 |
| C: Traffic volume of the road | 0.220 |
| D: Character of the road (Road to border, road for network, road to dead end) | 0.109 |
| F: Economy of the road side area | 0.131 |
| F: Number of buildings in vicinity of the bridges | 0.127 |

### (2) Priority of the Target Roads

Result of the prioritization of the target roads for the Study is shown in Table 2-4. Improvement of the existing bridge is the main objective of this study so that the road which has no bridge necessary to be improved shall be neglected from the target bridges. There are many temporary bridges including wooden bridge, Bailey bridge and other type of temporary bridge in Cambodia and they have high priority for replacement with a permanent bridge. Besides, there are lot of concrete bridge with one carriageway being constructed by the Cambodia in recent years. They have some durability for the existing traffic load compared with the temporary bridges.

They need to be replaced in the near future, however the urgency for the replacement is rather low compared with the temporary bridges. The road with temporary bridge and concrete bridge with one lane carriageway are picked up as target bridges. The target roads shall be prioritized to determine the strategy to improve the target bridges. The roads with concrete bridge with one lane carriageway are given half weight for priority to distinguish the roads with temporary bridges because they do not have high urgency to be replaced. The revised priorities of the target roads are shown in Table 2-5.

## Table 2-4Priority of the Target Roads of the Study

| Priority No. | Road No. | Evaluation Attribute | | | | | | Priority | Priority No. | Road No. | Evaluation Attribute | | | | | | Priority | Priority No. | Road No. | Evaluation Attribute | | | | | | Priority |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | A | B | C | D | E | F | | | | A | B | C | D | E | F | | | | A | B | C | D | E | F | |
| 1 | 57 | 9 | 9 | 9 | 9 | 9 | 9 | 9.009 | 57 | 140 | 9 | 7 | 5 | 2 | 1 | 9 | 6.194 | 113 | 155D | 3 | 7 | 5 | 7 | 5 | 9 | 5.151 |
| 2 | 57B | 9 | 9 | 9 | 9 | 9 | 9 | 9.009 | 58 | 1551 | 9 | 5 | 3 | 7 | 1 | 9 | 6.175 | 114 | 155F | 3 | 7 | 5 | 7 | 5 | 9 | 5.151 |
| 3 | 59 | 9 | 9 | 9 | 9 | 9 | 9 | 9.009 | 59 | 126 | 5 | 5 | 7 | 7 | 5 | 9 | 6.171 | 115 | 157 | 3 | 7 | 5 | 7 | 5 | 9 | 5.151 |
| 4 | 78 | 9 | 7 | 9 | 9 | 9 | 9 | 8.885 | 60 | 279 | 3 | 9 | 9 | 7 | 9 | 5 | 6.171 | 116 | 260A | 3 | 7 | 5 | 7 | 5 | 9 | 5.151 |
| 5 | 31 | 9 | 9 | 9 | 7 | 9 | 9 | 8.791 | 61 | 63 | 3 | 9 | 9 | 2 | 9 | 9 | 6.134 | 117 | 264B | 3 | 7 | 5 | 7 | 5 | 9 | 5.151 |
| 6 | 51 | 9 | 9 | 9 | 7 | 9 | 9 | 8.791 | 62 | 114 | 3 | 7 | 7 | 7 | 9 | 9 | 6.115 | 118 | 266F | 3 | 7 | 5 | 7 | 5 | 9 | 5.151 |
| 7 | 56 | 9 | 9 | 9 | 7 | 9 | 9 | 8.791 | 63 | 151B | 3 | 7 | 7 | 7 | 9 | 9 | 6.115 | 119 | 314 | 3 | 7 | 5 | 7 | 5 | 9 | 5.151 |
| 8 | 62 | 9 | 9 | 7 | 9 | 9 | 9 | 8.569 | 64 | 155 | 3 | 7 | 7 | 7 | 9 | 9 | 6.115 | 120 | 371D | 3 | 7 | 5 | 7 | 5 | 9 | 5.151 |
| 9 | 11 | 9 | 9 | 9 | 7 | 9 | 7 | 8.537 | 65 | 2620 | 7 | 7 | 5 | 7 | 1 | 9 | 6.035 | 121 | 380A | 3 | 7 | 5 | 7 | 5 | 9 | 5.151 |
| 10 | 68 | 9 | 7 | 7 | 9 | 9 | 9 | 8.445 | 66 | 132 | 3 | 7 | 9 | 7 | 5 | 9 | 6.031 | 122 | 387A | 3 | 7 | 5 | 7 | 5 | 9 | 5.151 |
| 11 | 76 | 9 | 7 | 9 | 7 | 9 | 7 | 8.413 | 67 | 314C | 3 | 5 | 7 | 7 | 9 | 9 | 5.991 | 123 | 152H | 3 | 7 | 5 | 2 | 9 | 9 | 5.130 |
| 12 | 72 | 9 | 7 | 9 | 9 | 5 | 9 | 8.361 | 68 | 130 | 3 | 9 | 7 | 7 | 9 | 7 | 5.985 | 124 | 156D | 3 | 7 | 7 | 2 | 9 | 5 | 5.062 |
| 13 | 61 | 9 | 9 | 7 | 7 | 9 | 9 | 8.351 | 69 | 44 | 5 | 9 | 5 | 2 | 9 | 9 | 5.958 | 125 | 153C | 3 | 5 | 5 | 7 | 5 | 9 | 5.027 |
| 14 | 41 | 9 | 9 | 9 | 7 | 5 | 9 | 8.267 | 70 | 377 | 3 | 7 | 7 | 7 | 9 | 7 | 5.861 | 126 | 317 | 3 | 5 | 5 | 7 | 5 | 9 | 5.027 |
| 15 | 33 | 9 | 7 | 7 | 9 | 9 | 7 | 8.191 | 71 | 264C | 7 | 7 | 3 | 7 | 3 | 9 | 5.857 | 127 | 377A | 3 | 5 | 5 | 7 | 5 | 9 | 5.027 |
| 16 | 48 | 9 | 7 | 7 | 9 | 9 | 7 | 8.191 | 72 | 135 | 3 | 9 | 5 | 7 | 9 | 9 | 5.799 | 128 | 155A | 3 | 5 | 5 | 2 | 9 | 9 | 5.006 |
| 17 | 138 | 9 | 7 | 9 | 2 | 9 | 9 | 8.122 | 73 | 154A | 3 | 9 | 5 | 7 | 9 | 9 | 5.799 | 129 | 269 | 3 | 5 | 5 | 2 | 9 | 9 | 5.006 |
| 18 | 260 | 9 | 5 | 9 | 7 | 7 | 7 | 8.027 | 74 | 157C | 3 | 9 | 5 | 7 | 9 | 9 | 5.799 | 130 | 314A | 3 | 7 | 3 | 9 | 5 | 9 | 4.929 |
| 19 | 159D | 9 | 7 | 7 | 7 | 7 | 9 | 7.965 | 75 | 277 | 3 | 9 | 5 | 7 | 9 | 9 | 5.799 | 131 | 266A | 3 | 7 | 5 | 7 | 3 | 9 | 4.889 |
| 20 | 73 | 9 | 9 | 7 | 7 | 9 | 5 | 7.843 | 76 | 315 | 3 | 9 | 5 | 7 | 9 | 9 | 5.799 | 132 | 317C | 3 | 5 | 3 | 7 | 7 | 9 | 4.849 |
| 21 | 71 | 9 | 9 | 7 | 7 | 5 | 9 | 7.827 | 77 | 129C | 5 | 5 | 5 | 7 | 5 | 9 | 5.731 | 133 | 46 | 5 | 7 | 5 | 2 | 1 | 9 | 4.786 |
| 22 | 373C | 9 | 9 | 7 | 7 | 5 | 9 | 7.827 | 78 | 270 | 3 | 9 | 7 | 7 | 9 | 5 | 5.731 | 134 | 159B | 3 | 9 | 5 | 7 | 5 | 5 | 4.767 |
| 23 | 314B | 9 | 7 | 5 | 7 | 9 | 9 | 7.787 | 79 | 316A | 3 | 5 | 7 | 7 | 7 | 9 | 5.729 | 135 | 2646 | 3 | 5 | 5 | 7 | 3 | 9 | 4.765 |
| 24 | 311 | 9 | 7 | 7 | 7 | 5 | 9 | 7.703 | 80 | 129 | 3 | 9 | 7 | 7 | 5 | 9 | 5.715 | 136 | 264 | 3 | 9 | 5 | 2 | 5 | 9 | 4.730 |
| 25 | 312B | 9 | 7 | 7 | 7 | 5 | 9 | 7.703 | 81 | 264A | 3 | 9 | 7 | 7 | 5 | 9 | 5.715 | 137 | 137 | 3 | 7 | 3 | 7 | 5 | 9 | 4.711 |
| 26 | 313 | 9 | 7 | 7 | 7 | 5 | 9 | 7.703 | 82 | 136A | 3 | 7 | 5 | 7 | 9 | 9 | 5.675 | 138 | 313A | 3 | 7 | 3 | 7 | 5 | 9 | 4.711 |
| 27 | 53 | 7 | 7 | 7 | 7 | 9 | 9 | 7.523 | 83 | 157B | 3 | 7 | 5 | 7 | 9 | 9 | 5.675 | 139 | 387 | 3 | 7 | 3 | 7 | 5 | 9 | 4.711 |
| 28 | 110 | 9 | 9 | 9 | 7 | 7 | 1 | 7.513 | 84 | 375 | 3 | 7 | 5 | 7 | 9 | 9 | 5.675 | 140 | 152G | 3 | 7 | 3 | 2 | 9 | 9 | 4.690 |
| 29 | 67 | 9 | 7 | 7 | 9 | 1 | 9 | 7.397 | 85 | 134B | 3 | 7 | 7 | 7 | 5 | 9 | 5.591 | 141 | 266 | 3 | 7 | 5 | 7 | 1 | 9 | 4.627 |
| 30 | 258D | 9 | 5 | 5 | 9 | 5 | 9 | 7.357 | 86 | 266D | 3 | 7 | 7 | 7 | 5 | 9 | 5.591 | 142 | 53A | 3 | 7 | 5 | 2 | 5 | 9 | 4.606 |
| 31 | 314D | 9 | 5 | 5 | 9 | 5 | 9 | 7.357 | 87 | 266E | 3 | 7 | 7 | 7 | 5 | 9 | 5.591 | 143 | 121 | 3 | 7 | 5 | 2 | 5 | 9 | 4.606 |
| 32 | 13 | 7 | 7 | 7 | 7 | 9 | 7 | 7.269 | 88 | 45 | 3 | 5 | 5 | 9 | 7 | 9 | 5.507 | 144 | 153B | 3 | 7 | 5 | 2 | 5 | 9 | 4.606 |
| 33 | 264D | 9 | 7 | 5 | 7 | 5 | 9 | 7.263 | 89 | 371 | 5 | 9 | 5 | 7 | 5 | 5 | 5.471 | 145 | 154C | 3 | 7 | 5 | 2 | 5 | 9 | 4.606 |
| 34 | 1488 | 9 | 5 | 3 | 7 | 9 | 9 | 7.223 | 90 | 266B | 3 | 5 | 7 | 7 | 5 | 9 | 5.467 | 146 | 154E | 3 | 7 | 5 | 2 | 5 | 9 | 4.606 |
| 35 | 380 | 9 | 7 | 7 | 7 | 5 | 5 | 7.195 | 91 | 373B | 3 | 7 | 5 | 7 | 7 | 9 | 5.413 | 147 | 154F | 3 | 7 | 5 | 2 | 5 | 9 | 4.606 |
| 36 | 261 | 9 | 5 | 5 | 7 | 7 | 7 | 7.147 | 92 | 372A | 3 | 7 | 5 | 9 | 5 | 9 | 5.369 | 148 | 155E | 3 | 7 | 5 | 2 | 5 | 9 | 4.606 |
| 37 | 378 | 9 | 5 | 5 | 7 | 5 | 9 | 7.139 | 93 | 52 | 5 | 7 | 5 | 2 | 5 | 9 | 5.310 | 149 | 157A | 3 | 7 | 5 | 2 | 5 | 9 | 4.606 |
| 38 | 312 | 9 | 7 | 5 | 7 | 5 | 7 | 7.009 | 94 | 317B | 3 | 5 | 5 | 7 | 7 | 9 | 5.289 | 150 | 265 | 3 | 7 | 5 | 2 | 5 | 9 | 4.606 |
| 39 | 147 | 5 | 9 | 7 | 7 | 9 | 9 | 6.943 | 95 | 319 | 3 | 5 | 5 | 7 | 7 | 9 | 5.289 | 151 | 370C | 3 | 7 | 5 | 2 | 5 | 9 | 4.606 |
| 40 | 55 | 7 | 9 | 5 | 9 | 9 | 5 | 6.917 | 96 | 153 | 3 | 9 | 5 | 7 | 5 | 9 | 5.275 | 152 | 383 | 3 | 7 | 5 | 2 | 5 | 9 | 4.606 |
| 41 | 317A | 9 | 5 | 3 | 9 | 5 | 9 | 6.917 | 97 | 268B | 3 | 9 | 5 | 7 | 5 | 9 | 5.275 | 153 | 377B | 3 | 5 | 3 | 7 | 5 | 9 | 4.587 |
| 42 | 381 | 9 | 7 | 7 | 2 | 5 | 7 | 6.904 | 98 | 370A | 3 | 9 | 5 | 7 | 5 | 9 | 5.275 | 154 | 374 | 3 | 5 | 5 | 7 | 1 | 9 | 4.503 |
| 43 | 58 | 3 | 9 | 9 | 9 | 9 | 9 | 6.897 | 99 | 373A | 3 | 9 | 5 | 7 | 5 | 9 | 5.275 | 155 | 53B | 3 | 5 | 5 | 2 | 5 | 9 | 4.482 |
| 44 | 382 | 9 | 9 | 5 | 2 | 5 | 9 | 6.842 | 100 | 373D | 3 | 9 | 5 | 7 | 5 | 9 | 5.275 | 156 | 152 | 3 | 5 | 5 | 2 | 5 | 9 | 4.482 |
| 45 | 42 | 5 | 7 | 7 | 7 | 9 | 9 | 6.819 | 101 | 156 | 3 | 9 | 5 | 2 | 9 | 9 | 5.254 | 157 | 376 | 3 | 5 | 5 | 2 | 5 | 9 | 4.482 |
| 46 | 118A | 9 | 5 | 7 | 9 | 5 | 1 | 6.781 | 102 | 154 | 3 | 7 | 9 | 2 | 5 | 7 | 5.232 | 158 | 265C | 3 | 5 | 7 | 2 | 5 | 5 | 4.414 |
| 47 | 264E | 9 | 7 | 5 | 7 | 1 | 9 | 6.739 | 103 | 266C | 3 | 9 | 7 | 7 | 1 | 9 | 5.191 | 159 | 265E | 3 | 5 | 7 | 2 | 1 | 9 | 4.398 |
| 48 | 156A | 3 | 9 | 9 | 7 | 9 | 9 | 6.679 | 104 | 124 | 3 | 7 | 5 | 7 | 5 | 9 | 5.151 | 160 | 265B | 3 | 7 | 5 | 2 | 5 | 7 | 4.352 |
| 49 | 267 | 3 | 9 | 9 | 7 | 9 | 9 | 6.679 | 105 | 133A | 3 | 7 | 5 | 7 | 5 | 9 | 5.151 | 161 | 312A | 3 | 7 | 1 | 7 | 5 | 9 | 4.271 |
| 50 | 2624 | 9 | 5 | 5 | 7 | 1 | 9 | 6.615 | 106 | 134 | 3 | 7 | 5 | 7 | 5 | 9 | 5.151 | 162 | 268A | 3 | 7 | 3 | 2 | 5 | 9 | 4.166 |
| 51 | 21 | 5 | 9 | 9 | 9 | 9 | 1 | 6.585 | 107 | 134A | 3 | 7 | 5 | 7 | 5 | 9 | 5.151 | 163 | 156C | 3 | 7 | 5 | 2 | 5 | 5 | 4.098 |
| 52 | 60 | 5 | 9 | 5 | 7 | 9 | 9 | 6.503 | 108 | 136 | 3 | 7 | 5 | 7 | 5 | 9 | 5.151 | 164 | 2647 | 3 | 5 | 3 | 7 | 1 | 9 | 4.063 |
| 53 | 64 | 3 | 9 | 9 | 7 | 9 | 7 | 6.425 | 109 | 153A | 3 | 7 | 5 | 7 | 5 | 9 | 5.151 | 165 | 152D | 3 | 5 | 3 | 2 | 5 | 9 | 4.042 |
| 54 | 43 | 7 | 9 | 5 | 7 | 3 | 9 | 6.421 | 110 | 154B | 3 | 7 | 5 | 7 | 5 | 9 | 5.151 | 166 | 152E | 3 | 5 | 3 | 2 | 5 | 9 | 4.042 |
| 55 | 2648 | 9 | 5 | 1 | 7 | 5 | 9 | 6.259 | 111 | 155B | 3 | 7 | 5 | 7 | 5 | 9 | 5.151 | 167 | 152F | 3 | 5 | 3 | 2 | 5 | 9 | 4.042 |
| 56 | 70 | 3 | 9 | 7 | 7 | 9 | 9 | 6.239 | 112 | 155C | 3 | 7 | 5 | 7 | 5 | 9 | 5.151 | 168 | 54 | 3 | 5 | 5 | 2 | 1 | 9 | 3.958 |

## Table 2-5 Revised Priority of the Target Roads

| Priority No. | Road No. | Evaluation Attribute | | | | | | Priority | Annulation of Completed, On-going, & Committed Projects | Priority (Final) | Priority No. | Road No. | Evaluation Attribute | | | | | | Priority | Annulation of Completed, On-going, & Committed Projects | Priority (Final) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | A | B | C | D | E | F | | | | | | A | B | C | D | E | F | | | |
| **1** | 11 | 9 | 9 | 9 | 7 | 9 | 7 | 8.537 | 1 | 8.537 | **44** | 383 | 3 | 7 | 5 | 2 | 5 | 9 | 4.606 | 1 | 4.606 |
| **2** | 73 | 9 | 9 | 7 | 7 | 9 | 5 | 7.843 | 1 | 7.843 | **45** | 374 | 3 | 5 | 5 | 7 | 1 | 9 | 4.503 | 1 | 4.503 |
| **3** | 314D | 9 | 5 | 5 | 9 | 5 | 9 | 7.357 | 1 | 7.357 | **46** | 53B | 3 | 5 | 5 | 2 | 5 | 9 | 4.482 | 1 | 4.482 |
| **4** | 42 | 5 | 7 | 7 | 7 | 9 | 9 | 6.819 | 1 | 6.819 | **47** | 265C | 3 | 5 | 7 | 2 | 5 | 5 | 4.414 | 1 | 4.414 |
| **5** | 267 | 3 | 9 | 9 | 7 | 9 | 9 | 6.679 | 1 | 6.679 | **48** | 265E | 3 | 5 | 7 | 2 | 1 | 9 | 4.398 | 1 | 4.398 |
| **6** | 2624 | 9 | 5 | 5 | 7 | 1 | 9 | 6.615 | 1 | 6.615 | **49** | 62 | 9 | 9 | 7 | 9 | 9 | 9 | 8.569 | 0.5 | 4.285 |
| **7** | 70 | 3 | 9 | 7 | 7 | 9 | 9 | 6.239 | 1 | 6.239 | **50** | 68 | 9 | 7 | 7 | 9 | 9 | 9 | 8.445 | 0.5 | 4.223 |
| **8** | 279 | 3 | 9 | 9 | 7 | 9 | 5 | 6.171 | 1 | 6.171 | **51** | 152D | 3 | 5 | 3 | 2 | 5 | 9 | 4.042 | 1 | 4.042 |
| **9** | 151B | 3 | 7 | 7 | 7 | 9 | 9 | 6.115 | 1 | 6.115 | **52** | 152F | 3 | 5 | 3 | 2 | 5 | 9 | 4.042 | 1 | 4.042 |
| **10** | 155 | 3 | 7 | 7 | 7 | 9 | 9 | 6.115 | 1 | 6.115 | **53** | 260 | 9 | 5 | 9 | 7 | 7 | 7 | 8.027 | 0.5 | 4.014 |
| **11** | 2620 | 7 | 7 | 5 | 7 | 1 | 9 | 6.035 | 1 | 6.035 | **54** | 159D | 9 | 7 | 7 | 7 | 7 | 9 | 7.965 | 0.5 | 3.983 |
| **12** | 314C | 3 | 5 | 7 | 7 | 9 | 9 | 5.991 | 1 | 5.991 | **55** | 313 | 9 | 7 | 7 | 7 | 5 | 9 | 7.703 | 0.5 | 3.852 |
| **13** | 377 | 3 | 7 | 7 | 7 | 9 | 7 | 5.861 | 1 | 5.861 | **56** | 67 | 9 | 7 | 7 | 9 | 1 | 9 | 7.397 | 0.5 | 3.699 |
| **14** | 264C | 7 | 7 | 3 | 7 | 3 | 9 | 5.857 | 1 | 5.857 | **57** | 261 | 9 | 5 | 5 | 7 | 7 | 7 | 7.147 | 0.5 | 3.574 |
| **15** | 277 | 3 | 9 | 5 | 7 | 9 | 9 | 5.799 | 1 | 5.799 | **58** | 147 | 5 | 9 | 7 | 7 | 9 | 9 | 6.943 | 0.5 | 3.472 |
| **16** | 316A | 3 | 5 | 7 | 7 | 7 | 9 | 5.729 | 1 | 5.729 | **59** | 156A | 3 | 9 | 9 | 7 | 9 | 9 | 6.679 | 0.5 | 3.340 |
| **17** | 375 | 3 | 7 | 5 | 7 | 9 | 9 | 5.675 | 1 | 5.675 | **60** | 114 | 3 | 7 | 7 | 7 | 9 | 9 | 6.115 | 0.5 | 3.058 |
| **18** | 373B | 3 | 7 | 5 | 7 | 7 | 9 | 5.413 | 1 | 5.413 | **61** | 130 | 3 | 9 | 7 | 7 | 9 | 7 | 5.985 | 0.5 | 2.993 |
| **19** | 372A | 3 | 7 | 5 | 9 | 5 | 9 | 5.369 | 1 | 5.369 | **62** | 154A | 3 | 9 | 5 | 7 | 9 | 9 | 5.799 | 0.5 | 2.900 |
| **20** | 373D | 3 | 9 | 5 | 7 | 5 | 9 | 5.275 | 1 | 5.275 | **63** | 135 | 3 | 9 | 5 | 7 | 9 | 9 | 5.799 | 0.5 | 2.900 |
| **21** | 156 | 3 | 9 | 5 | 2 | 9 | 9 | 5.254 | 1 | 5.254 | **64** | 157C | 3 | 9 | 5 | 7 | 9 | 9 | 5.799 | 0.5 | 2.900 |
| **22** | 154 | 3 | 7 | 9 | 2 | 5 | 7 | 5.232 | 1 | 5.232 | **65** | 129C | 5 | 5 | 5 | 7 | 5 | 9 | 5.731 | 0.5 | 2.866 |
| **23** | 266C | 3 | 9 | 7 | 7 | 1 | 9 | 5.191 | 1 | 5.191 | **66** | 129 | 3 | 9 | 7 | 7 | 5 | 9 | 5.715 | 0.5 | 2.858 |
| **24** | 136 | 3 | 7 | 5 | 7 | 5 | 9 | 5.151 | 1 | 5.151 | **67** | 136A | 3 | 7 | 5 | 7 | 9 | 9 | 5.675 | 0.5 | 2.838 |
| **25** | 154B | 3 | 7 | 5 | 7 | 5 | 9 | 5.151 | 1 | 5.151 | **68** | 157B | 3 | 7 | 5 | 7 | 9 | 9 | 5.675 | 0.5 | 2.838 |
| **26** | 155B | 3 | 7 | 5 | 7 | 5 | 9 | 5.151 | 1 | 5.151 | **69** | 134B | 3 | 7 | 7 | 7 | 5 | 9 | 5.591 | 0.5 | 2.796 |
| **27** | 371D | 3 | 7 | 5 | 7 | 5 | 9 | 5.151 | 1 | 5.151 | **70** | 266E | 3 | 7 | 7 | 7 | 5 | 9 | 5.591 | 0.5 | 2.796 |
| **28** | 380A | 3 | 7 | 5 | 7 | 5 | 9 | 5.151 | 1 | 5.151 | **71** | 317B | 3 | 5 | 5 | 7 | 7 | 9 | 5.289 | 0.5 | 2.645 |
| **29** | 152H | 3 | 7 | 5 | 2 | 9 | 9 | 5.130 | 1 | 5.13 | **72** | 153 | 3 | 9 | 5 | 7 | 5 | 9 | 5.275 | 0.5 | 2.638 |
| **30** | 156D | 3 | 7 | 7 | 2 | 9 | 5 | 5.062 | 1 | 5.062 | **73** | 268B | 3 | 9 | 5 | 7 | 5 | 9 | 5.275 | 0.5 | 2.638 |
| **31** | 155A | 3 | 5 | 5 | 2 | 9 | 9 | 5.006 | 1 | 5.006 | **74** | 133A | 3 | 7 | 5 | 7 | 5 | 9 | 5.151 | 0.5 | 2.576 |
| **32** | 317C | 3 | 5 | 3 | 7 | 7 | 9 | 4.849 | 1 | 4.849 | **75** | 314 | 3 | 7 | 5 | 7 | 5 | 9 | 5.151 | 0.5 | 2.576 |
| **33** | 46 | 5 | 7 | 5 | 2 | 1 | 9 | 4.786 | 1 | 4.786 | **76** | 387A | 3 | 7 | 5 | 7 | 5 | 9 | 5.151 | 0.5 | 2.576 |
| **34** | 159B | 3 | 9 | 5 | 7 | 5 | 5 | 4.767 | 1 | 4.767 | **77** | 153C | 3 | 5 | 5 | 7 | 5 | 9 | 5.027 | 0.5 | 2.514 |
| **35** | 2646 | 3 | 5 | 5 | 7 | 3 | 9 | 4.765 | 1 | 4.765 | **78** | 313A | 3 | 7 | 3 | 7 | 5 | 9 | 4.711 | 0.5 | 2.356 |
| **36** | 137 | 3 | 7 | 3 | 7 | 5 | 9 | 4.711 | 1 | 4.711 | **79** | 387 | 3 | 7 | 3 | 7 | 5 | 9 | 4.711 | 0.5 | 2.356 |
| **37** | 266 | 3 | 7 | 5 | 7 | 1 | 9 | 4.627 | 1 | 4.627 | **80** | 152G | 3 | 7 | 3 | 2 | 9 | 9 | 4.690 | 0.5 | 2.345 |
| **38** | 53A | 3 | 7 | 5 | 2 | 5 | 9 | 4.606 | 1 | 4.606 | **81** | 121 | 3 | 7 | 5 | 2 | 5 | 9 | 4.606 | 0.5 | 2.303 |
| **39** | 154C | 3 | 7 | 5 | 2 | 5 | 9 | 4.606 | 1 | 4.606 | **82** | 153B | 3 | 7 | 5 | 2 | 5 | 9 | 4.606 | 0.5 | 2.303 |
| **40** | 154E | 3 | 7 | 5 | 2 | 5 | 9 | 4.606 | 1 | 4.606 | **83** | 152 | 3 | 5 | 5 | 2 | 5 | 9 | 4.482 | 0.5 | 2.241 |
| **41** | 154F | 3 | 7 | 5 | 2 | 5 | 9 | 4.606 | 1 | 4.606 | **84** | 265B | 3 | 7 | 5 | 2 | 5 | 7 | 4.352 | 0.5 | 2.176 |
| **42** | 155E | 3 | 7 | 5 | 2 | 5 | 9 | 4.606 | 1 | 4.606 | **85** | 268A | 3 | 7 | 3 | 2 | 5 | 9 | 4.166 | 0.5 | 2.083 |
| **43** | 265 | 3 | 7 | 5 | 2 | 5 | 9 | 4.606 | 1 | 4.606 | **86** | 156C | 3 | 7 | 5 | 2 | 5 | 5 | 4.098 | 0.5 | 2.049 |

Remarks: Red shows temporary bridge and Yellow shows overflow or one lane bridge

### (3) Focus on the Group of High Priority Roads

The road sector will improve 2- and 3-digit roads to integrate national and regional areas. Bridges are a part of roads and the roads are one of important infrastructure to sustain the development of the region. Hence the roads shall be selected as a part of road network in a region and road development plan shall be established as a group for a region. Short-term plan should be selected taking into considered priority of the target roads together with project cost. The step to select the target roads is as follows.

1) Focus on the high priority roads
2) Grouping the roads considering the regional development
3) Prioritization of the target roads.

High priority roads are distinguished into 5 groups as shown in Table 2-6. Those groups are located along NR7, NR1 (Vietnam border), NR5, NR6 and NR3 as shown in Figure 2-1. Total demand for bridge replacement can be obtained by multiplication of weight for the target roads and the number of bridges on the road. Average weight for bridge in each group is calculated by total weight divided by the total number of bridges on the road. Group1 and 2 are recommended for improvement as first priority groups in short-term plan for the following reasons.

1) The Group1 includes the NR11and NR73, which is one of the highest priority roads among the target roads
2) Average weight of bridge importance in Group2 is the highest compared to other alternative groups.

**Table 2-6 Group of the Target Roads**

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Group1 (NR7)** | Road No. | 11 | 70 | 73 | 277 | 279 | 372A | 373B | 373D | 375 | 377 | Total | Average |
| | Priority | 8.54 | 6.24 | 7.84 | 5.80 | 6.17 | 5.37 | 5.41 | 5.28 | 5.68 | 5.86 | | |
| | Br. No | 2 | 2 | 6 | 2 | 1 | 5 | 1 | 10 | 3 | 12 | 44 | |
| | Weight | 16.71 | 12.48 | 47.06 | 13.36 | 6.17 | 26.85 | 5.41 | 52.75 | 17.025 | 70.33 | 268.15 | **6.09** |
| **Group2 (NR1)** | Road No. | 314C | 314D | 316A | | | | | | | | | |
| | Priority | 5.99 | 7.36 | 5.73 | | | | | | | | | |
| | Br. No | 1 | 1 | 1 | | | | | | | | 3 | |
| | Weight | 5.991 | 7.36 | 5.73 | | | | | | | | 19.08 | **6.36** |
| Group3 (NR5) | Road No. | 151B | 154 | 155 | 156 | 154B | 42 | | | | | | |
| | Priority | 6.12 | 5.23 | 6.12 | 5.25 | 5.15 | 6.82 | | | | | | |
| | Br. No | 4 | 3 | 6 | 2 | 1 | 1 | | | | | 17 | |
| | Weight | 24.4 | 15.6 | 36.7 | 10.5 | 5.1 | 6.8 | | | | | 99.1 | 5.83 |
| Group4 (NR6) | Road No. | 264C | 266C | 267 | 2624 | 2620 | | | | | | | |
| | Priority | 5.86 | 5.19 | 6.68 | 6.62 | 6.04 | | | | | | | |
| | Br. No | 2 | 1 | 1 | 1 | 1 | | | | | | 6 | |
| | Weight | 11.71 | 5.19 | 6.68 | 6.62 | 6.04 | | | | | | 36.24 | 6.04 |
| Group5 (NR3) | Road No. | 136 | | | | | | | | | | | |
| | Priority | 5.151 | | | | | | | | | | | |
| | Br. No | 1 | | | | | | | | | | 1 | |
| | Weight | 5.15 | | | | | | | | | | 5.15 | 5.15 |

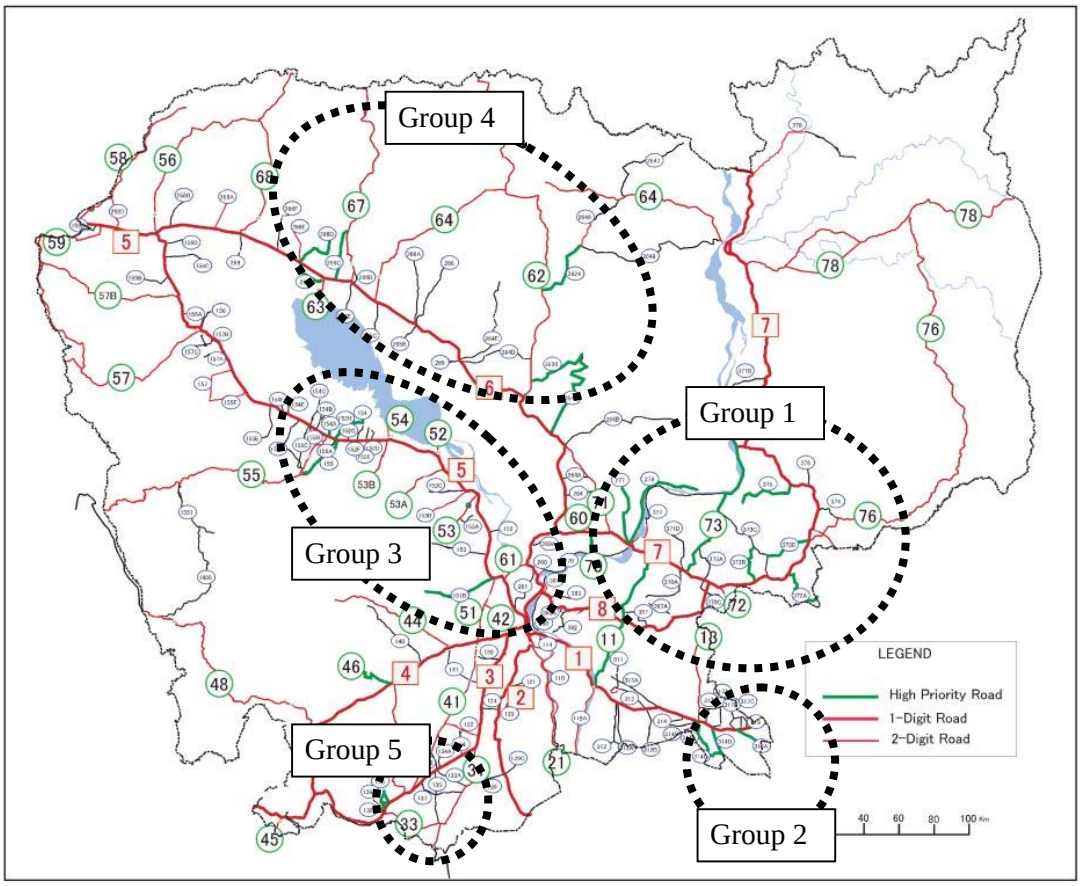



**Figure 2-1 Location Map of Priority Roads**

# 3. BRIDGE SURVEY

Survey team confirmed conditions of the target roads including development plan for the roads by the Cambodia and the donor countries based on the bridge inventory data prepared by the Heavy Equipment Center (HEC) in 2006. The survey team confirmed that the majority of the 2-digit roads are completed or committed to be improved by the donor countries and agencies including China, Korea and Thailand Asian Development Bank. Many one lane concrete bridges that were constructed from the year 1993 to 2005 by the Cambodia were confirmed on 3-digit roads.

With confirmation on the inventory and inspection data, six roads could not be confirmed because of the duplication or wrong entries to the data. The roads already improved or committed by the donor countries, and roads that could not be identified on the database or site survey will not be included as the target bridges.

Number of bridges and types of bridges listed in the inventory data from the HEC and results of the site survey are not consistent. Some bridges confirmed through the site survey are not listed in the inventory data. Many bridges are already replaced, however, data in the bridge inventory from the HEC is not updated therefore the inventory data collected through site survey by the Study Team will be treated as the latest data for selection of the prioritized road in the study.

## 3.1 Bridge Inventory Survey

### (1) Outline of Bridge Inventory Survey

The bridge inventory survey was carried out by the local survey company in Cambodia from April to September 2012. The purposes of the survey were as follows.

1) To identify the target roads
2) To identify the temporary bridges
3) To inspect degree of bridge deficiency
4) To prioritize the target bridges
5) To design and estimate cost for bridge replacement

The target roads were selected based on the bridge list which was made in 2006 by the HEC. Some box culverts, water gates and causeways were also investigated to evaluate whether the structure should be replaced with a bridge. Number of surveyed roads is 168 and numbers of surveyed structures are shown in Table 3-1.

**Table 3-1 Structures investigated through the survey**

| Road | Structure | | | |
|---|---|---|---|---|
| | **Bridge** | **Box culvert** | **Water gate** | **Causeway** |
| 168 | 1205 | 44 | 26 | 3 |

Source: Study Team

### (2) Contents of Bridge Inspection Manual

The bridge inspection manual including the methods of measuring bridge dimensions and evaluation for degree of bridge deficiencies is prepared for the site survey. The contents of inspection sheet are considered to evaluate the scale of new bridges which will replace temporary bridges and to collect information for bridge design. Items of the information to be collected are as follows.

1) General Information
2) Environment and social consideration
3) Dimensions of Super Structure
4) Dimensions of Sub-Structure
5) Photos of Bridge
6) Condition rating of bridge deficiency
7) Photos of Bridge Deficiency

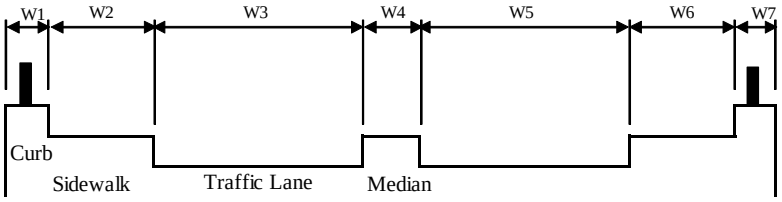
### (3) Bridge Inspection Sheet

Results of bridge inspection were recorded in the following sheets for each bridge and the form of inventory and inspection sheets are shown in Table 3-2 and 3-3.

1) General Information of the Bridge Inventory
2) Environment and social consideration
3) Dimensions of structure and condition rating of bridge deficiency
4) Photo of bridge
5) Photo of bridge deficiency

## Table 3-2 General Information of the Bridge Inventory

| **1. General Information of the Bridge Inventory** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Inspector : | Date | Month | Year | 1.2 Coordinate | ° | ' | '' | |
| 1.1 Inspection date | | | 2012 | North latitude | | | | |
| 1.1 Bridge Name | | | | East longitude | | | | |
| 1.1 Province | | | | 1.1 Road Number | | | | |
| 1.1 River Name | | | | 1.4 Width of River (m) | | | | |
| | Date | Month | Year | 1.6 Geographical features | | | | |
| 1.3 Construction Year | | | | 1.7 Clearance (m) | | | | |
| 1.9 Loading capacity (t) | | | | 1.8 Maximum high watar level (m) | | | | |
| 1.9 Width limit (m) | | | | 1.9 Vertical clearance(m) | | | | |
| 1.5 Particle size | | | | | | | | |
| 1.10 Type of the life line | | | | | | | | |
| 1.11 Material of surface layer | | | | | | | | |
| 1.12 Material of Deck | | | | | | | | |
| 1.13 Material of Guardrail | | | | | | | | |
| 1.14 Embankment protection | | | | | | | | |
| 2.3 Cross sections | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Total width |
| W (cm) | | | | | | | | - |




| 1.15 Type of structure | Number of Structure | 1.15 Land Use along Route | Length (m) |
|---|---|---|---|
| 1) Residence | | 1) Residential area | |
| 2) Commercial Building (Shop, Restaurant, Kiosk) | | 2) Commercial/ Business area | |
| 3) Workshop (for food, commodity, artifact, vehicle) | | 3) Factory area | |
| 4) Factory | | 4) Firm land | |
| 5) Stall | | 5) Forest | |
| 7) Other Business office | | 6) Wetland | |
| 8) Public Building | | 7) Grass Land | |
| 9) Others | | 8) Others | |

## Table 3-3 Dimensions of Surer Structure

**2. Dimensions of Super Structure**

| Bridge Length (m) | 0.00 |
|---|---|

| 2.1 Span No. | 2.4 Type of bridge | | 2.4 Type of girder | | 2.1 Hight of girder (cm) | 2.2 Length of span (m) |
|---|---|---|---|---|---|---|
| 1 | | | | | | |
| 2 | | | | | | |
| 3 | | | | | | |
| 4 | | | | | | |
| 5 | | | | | | |
| 6 | | | | | | |
| 7 | | | | | | |
| 8 | | | | | | |
| 9 | | | | | | |
| 10 | | | | | | |

**3. Dimensions of Sub Structure**

| 2.1 Item | 3.2 Type of abutment and pier | | 3.1 Height (m) | Material of Pile | |
|---|---|---|---|---|---|
| A1 | | | | | |
| A2 | | | | | |
| P1 | | | | | |
| P2 | | | | | |
| P3 | | | | | |
| P4 | | | | | |
| P5 | | | | | |
| P6 | | | | | |
| P7 | | | | | |
| P8 | | | | | |
| P9 | | | | | |

**5. Condition rating of bridge deficiency**

| Item | Rating |
|---|---|
| 5.1 Holes on the concrete deck slab | |
| 5.2 Deformation of steel main girder | |
| 5.3 Collapse of the slope protection at abutment | |
| 5.4 Inclination of abutment | |
| 5.4 Inclination of pier | |
| 5.5 Scour at foundation of abutment | |
| 5.6 Scour at foundation of pier | |

## 3.2 Result of the Bridge Survey

### (1) Target roads for the Survey

As shown in Table 3-4, the target roads for the inventory survey are classified into four categories.

1) Roads that have already been improved or are committed to be improved by donor countries.(Green in the Table)
2) There is no temporary bridge on the road. (Light blue)
3) One lane bridge and bridge over flow by flood water constructed by the Cambodia on the road.(Yellow)
4) Temporary bridges including Bailey bridges, wooden bridges are remaining on the roads. (Red)

Each group of roads is distinguished by green for No 1) roads, light blue for No 2) roads, yellow is for No3) roads and red for No 4) roads in Figure 3-1 and Table 3-4 respectively. The objective of the project is to plan the replacement of temporary bridges on the roads, thus the prioritized roads for the bridge replacements will be selected from the road category No 3) and No.4).

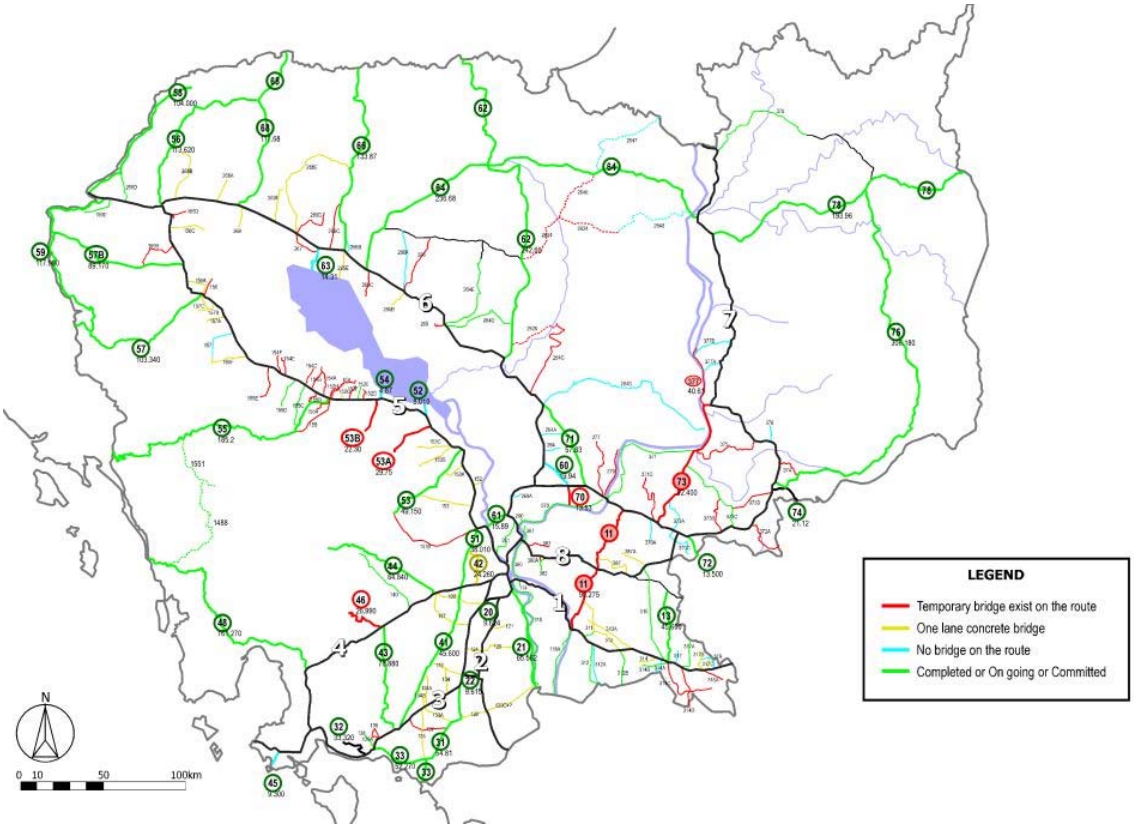



**Figure 3-1 Road Network and the Target Roads**

**Table 3-4 List of the target roads for inventory survey**

| No. | Road No. | Number of Bridge | Type of Bridge | | | | | No. | Road No. | Number of Bridge | Type of Bridge | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Bailey | Wood | Steel | Concrete | Other | | | | Bailey | Wood | Steel | Concrete | Other |
| 1 | 11 | 18 | 4 | | 8 | 6 | | 43 | 126 | 1 | | | | 1 | |
| 2 | 13 | 8 | 3 | | 1 | 4 | | 44 | 129 | 1 | | | | 1 | |
| 3 | 21 | 66 | 37 | | 17 | 12 | | 45 | 129C | 1 | | | | 1 | |
| 4 | 31 | 6 | 1 | | | 5 | | 46 | 130 | 9 | | | 1 | 8 | |
| 5 | 33 | 12 | 3 | | | 9 | | 47 | 132 | 1 | | | | 1 | |
| 6 | 41 | 16 | | | | 16 | | 48 | 133A | 4 | | | | 4 | |
| 7 | 42 | 6 | | | | 6 | | 49 | 134 | 1 | | | | 1 | |
| 8 | 43 | 35 | 31 | | | 4 | | 50 | 134A | 1 | | | | 1 | |
| 9 | 44 | 13 | 11 | 1 | | 1 | | 51 | 134B | 3 | | | | 3 | |
| 10 | 45 | 0 | | | | | | 52 | 135 | 2 | | | | 2 | |
| 11 | 46 | 4 | 3 | | 1 | | | 53 | 136 | 2 | | 1 | | 1 | |
| 12 | 48 | 39 | | | | 39 | | 54 | 136A | 3 | | | | 3 | |
| 13 | 51 | 3 | | | | 3 | | 55 | 137 | 6 | 1 | | | 5 | |
| 14 | 52 | 0 | | | | | | 56 | 138 | 3 | | | | 3 | |
| 15 | 53 | 11 | | 1 | | 10 | | 57 | 140 | 6 | | 1 | 1 | 4 | |
| 16 | 53A | 1 | 1 | | | | | 58 | 147 | 4 | | | | 4 | |
| 17 | 53B | 3 | | | 2 | 1 | | 59 | 151B | 4 | 4 | | | | |
| 18 | 54 | 0 | | | | | | 60 | 152 | 1 | | | | 1 | |
| 19 | 55 | 116 | 93 | 17 | 1 | 5 | | 61 | 152D | 3 | | 2 | | 1 | |
| 20 | 56 | 19 | | | | 19 | | 62 | 152E | 2 | | 1 | | 1 | |
| 21 | 57 | 19 | | | | 19 | | 63 | 152F | 1 | | 1 | | | |
| 22 | 57B | 24 | | | | 21 | 3 | 64 | 152G | 1 | | | | 1 | |
| 23 | 58 | 3 | | 2 | | 1 | | 65 | 152H | 2 | | 1 | | 1 | |
| 24 | 59 | 12 | | | | 12 | | 66 | 153 | 1 | | | | 1 | |
| 25 | 60 | 0 | | | | | | 67 | 153A | 3 | | | | 3 | |
| 26 | 61 | 0 | | | | | | 68 | 153B | 4 | | | | 4 | |
| 27 | 62 | 28 | | | | 28 | | 69 | 153C | 1 | | | | 1 | |
| 28 | 63 | 0 | | | | | | 70 | 154 | 6 | | 2 | 3 | 1 | |
| 29 | 64 | 54 | 18 | | | 30 | 6 | 71 | 154A | 7 | | 1 | | 6 | |
| 30 | 67 | 39 | | | | 39 | | 72 | 154B | 1 | | 1 | | | |
| 31 | 68 | 31 | | | | 31 | | 73 | 154C | 3 | | 2 | | 1 | |
| 32 | 70 | 3 | 2 | | | 1 | | 74 | 154E | 2 | | 2 | | | |
| 33 | 71 | 2 | | | | 2 | | 75 | 154F | 4 | | 3 | | 1 | |
| 34 | 72 | 1 | | | | 1 | | 76 | 155 | 14 | 1 | 5 | 2 | 6 | |
| 35 | 73 | 16 | 6 | | 1 | 9 | | 77 | 155A | 1 | 1 | | | | |
| 36 | 76 | 47 | 19 | 14 | | 14 | | 78 | 155B | 6 | | 6 | | | |
| 37 | 78 | 13 | | | | 13 | | 79 | 155C | 2 | | 1 | | 1 | |
| 38 | 110 | 69 | | 2 | | 67 | | 80 | 155D | 2 | | | 1 | 1 | |
| 39 | 114 | 1 | | | 1 | | | 81 | 155E | 5 | | 1 | | 4 | |
| 40 | 118A | 42 | 1 | | | 41 | | 82 | 155F | 4 | | | | 3 | 1 |
| 41 | 121 | 1 | | | | 1 | | 83 | 156 | 9 | 2 | | | 7 | |
| 42 | 124 | 1 | | | | 1 | | 84 | 156A | 5 | | | | 5 | |

| No. | Road No. | Number of | Type of Bridge | | | | | No. | Road No. | Number of Bridge | Type of Bridge | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Bailey | Wood | Steel | Concrete | Other | | | | Bailey | Wood | Steel | Concrete | Other |
| 85 | 156C | 13 | | | | 12 | 1 | 127 | 314 | 1 | | | | 1 | |
| 86 | 156D | 9 | 1 | 3 | | 5 | | 128 | 314A | 0 | | | | | |
| 87 | 157 | 0 | | | | | | 129 | 314B | 1 | | | | 1 | |
| 88 | 157A | 1 | | | | 1 | | 130 | 314C | 2 | 1 | | | 1 | |
| 89 | 157B | 2 | | | | 2 | | 131 | 314D | 1 | 1 | | | | |
| 90 | 157C | 3 | | | | 3 | | 132 | 315 | 6 | | | | 5 | 1 |
| 91 | 159B | 13 | 1 | | | 12 | | 133 | 316A | 1 | 1 | | | | |
| 92 | 159D | 6 | | | | 6 | | 134 | 317 | 0 | | | | | |
| 93 | 258D | 1 | | | | | 1 | 135 | 317A | 1 | | | | 1 | |
| 94 | 260 | 1 | | | | 1 | | 136 | 317B | 1 | | | | 1 | |
| 95 | 260A | 0 | | | | | | 137 | 317C | 2 | | | | 2 | |
| 96 | 261 | 7 | | | | 7 | | 138 | 319 | 0 | | | | | |
| 97 | 264 | 0 | | | | | | 139 | 370A | 0 | | | | | |
| 98 | 264A | 0 | | | | | | 140 | 370C | 0 | | | | | |
| 99 | 264B | 0 | | | | | | 141 | 371 | 10 | 4 | | | 6 | |
| 100 | 264C | 3 | | 2 | | 1 | | 142 | 371D | 1 | 1 | | | | |
| 101 | 264D | 2 | | | | 2 | | 143 | 372A | 5 | 5 | | | | |
| 102 | 264E | 9 | | | | 8 | 1 | 144 | 373A | 0 | | | | | |
| 103 | 265 | 1 | | 1 | | | | 145 | 373B | 1 | | | | 1 | |
| 104 | 265B | 2 | | | | 2 | | 146 | 373C | 5 | | | | 5 | |
| 105 | 265C | 4 | | 1 | | 3 | | 147 | 373D | 12 | | 11 | | | 1 |
| 106 | 265E | 1 | | | | 1 | | 148 | 374 | 2 | 2 | | | | |
| 107 | 266 | 4 | 1 | | | 3 | | 149 | 375 | 5 | | 3 | | 2 | |
| 108 | 266A | 0 | | | | | | 150 | 376 | 0 | | | | | |
| 109 | 266B | 0 | | | | | | 151 | 377 | 12 | 5 | 1 | 6 | | |
| 110 | 266C | 3 | 1 | | | 2 | | 152 | 377A | 0 | | | | | |
| 111 | 266D | 1 | | | | 1 | | 153 | 377B | 0 | | | | | |
| 112 | 266E | 5 | | | | 5 | | 154 | 378 | 7 | | | | 7 | |
| 113 | 266F | 1 | | | | 1 | | 155 | 380 | 10 | | | | 7 | 3 |
| 114 | 267 | 2 | | | 1 | 1 | | 156 | 380A | 2 | 1 | | | 1 | |
| 115 | 268A | 5 | | | | 5 | | 157 | 381 | 4 | | | | 3 | 1 |
| 116 | 268B | 2 | | | | 2 | | 158 | 382 | 1 | | | | 1 | |
| 117 | 269 | 1 | | | | 1 | | 159 | 383 | 9 | 5 | | | 1 | 3 |
| 118 | 270 | 19 | 4 | | 3 | 12 | | 160 | 387 | 2 | | | | 2 | |
| 119 | 277 | 4 | 2 | | | 2 | | 161 | 387A | 2 | | | | 2 | |
| 120 | 279 | 9 | 1 | | | 8 | | 162 | 1488 | 5 | 1 | | | 3 | 1 |
| 121 | 311 | 1 | | | | 1 | | 163 | 1551 | 13 | 1 | 12 | | | |
| 122 | 312 | 1 | | | | | 1 | 164 | 2620 | 6 | 1 | | | 5 | |
| 123 | 312A | 0 | | | | | | 165 | 2624 | 4 | 1 | | | 3 | |
| 124 | 312B | 1 | | | | 1 | | 166 | 2646 | 4 | 2 | | | | 2 |
| 125 | 313 | 5 | | | | 5 | | 167 | 2647 | 0 | | | | | |
| 126 | 313A | 1 | | | | 1 | | 168 | 2648 | 0 | | | | | |
| | | | | | | | | Total | | 1205 | 285 | 102 | 50 | 742 | 26 |

### (2) Bridge Condition

1) Outline of Bridges

The 168 roads including 25 roads which have no bridge on the roads are investigated in this study. 1,205 bridges are investigated through the survey. Bailey bridge type , wooden bridge type, steel bridge type, concrete bridge type including pre-stressed concrete bridge are identified in the Study.

2) Number of bridges and traffic lanes

Many wooden bridges and Bailey bridges have been replaced to concrete bridge or box culvert compared with bridge inventory of 2006. Total number of bridges in 2012 is reduced to 1,205 compared to 1,337 in 2006 because large numbers of wooden bridges have been replaced with box culverts and box culverts were not counted in this survey. Many bridges are improved from one lane to two lanes. Summary of the data for each type of bridge and traffic lane are shown in Table 3-5.

**Table 3-5 Summary of Bridge Type**

| Road Classification | Surveyed Year | Bridge type | | | | | | Total | Number of Traffic Lane | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Bailey | Wood | Steel | Concrete | Stone | Other | | Single | Double |
| 2-digit | 2006 | 204 | 244 | 43 | 100 | 8 | 0 | 599 | 512 | 87 |
| | 2012 | 232 | 35 | 31 | 360 | 0 | 10 | 668 | 295 | 364 |
| 3-digit | 2006 | 185 | 214 | 42 | 281 | | | 722 | 680 | 42 |
| | 2012 | 47 | 56 | 19 | 368 | | 15 | 505 | 310 | 180 |
| 4-digit | 2006 | 2 | 4 | | 10 | | | 16 | 12 | 4 |
| | 2012 | 6 | 12 | | 11 | | 3 | 32 | 19 | 10 |
| Sub total | 2006 | 391 | 462 | 85 | 391 | 8 | 0 | 1337 | 1204 | 133 |
| | 2012 | 285 | 103 | 50 | 739 | 0 | 28 | 1205 | 624 | 554 |

Note: Other means under construction

3) Condition of the target bridges

The Study Team investigated bridge deficiencies and damage of bridges suffered by the flooding of 2011. The concrete deck on some of bridges has been badly deteriorated as shown in Photo 3-1. The foundation is scored and the cracks appeared on the wing wall of abutment of the bridge located on NR64 as shown in Photo 3-2

**Photo 3-1 Bridge on NR21**

**Photo 3-2 Bridge on NR64**

Approach road has been washed away at the back of the abutment by the flooding of 2011. The traffic could not pass on the bridge on PR312B as shown Photo 3-3. The water level over the bridge reaches about 6m from the elevation on the deck during the rainy season. The bridge is located on PR265C along the Tonle Sap as shown in Photo 3-4

**Photo 3-3 Bridge on PR312B**

**Photo 3-4Bridge on PR265C**

4) Structure on the target roads

Structures other than the bridge are out of scope of the study however the Study Team investigated some box culverts, water gates and causeways as those structures may be replaced with bridges. Box culvert on PR264D is shown in Photo 3-5, water gate on PR154A is shown in Photo 3-6, and causeway on PR266E is shown in Photo 3-7.



**Photo 3-5 Box Culvert** **Photo 3-6 Water Gate** **Photo 3-7 Causeway**

### (3) Selection of Bridge Replacement

The bridges are classified into following types of bridge according to the bridge inspection survey. Those types of bridge shall be classified into a group of permanent, temporally, over flow and one lane bridge for bridge replacement plan as shown in Table 3-6. The groups of bridge which should be replaced with permanent bridge are temporary, over flow and one lane bridge excluding the bridge length less than 7m.

1) Permanent bridge including steel bridge, concrete bridge, and bridge under construction and committed
2) Temporary bridge including wooden bridge bailey bridge, steel bridge concrete bridge and bridge condition of grade 3
3) Bridges over flow by flood water
4) One lane bridge of steel and concrete bridge
5) Bridges which length less than 7m

**Table 3-6 Classification of bridge**

| Group of Classification | Num. of Bridge | Type of Bridge | | | | |
|---|---|---|---|---|---|---|
| Permanent Bridge | 903 | Steel | Concrete | Under construction | | |
| Temporary Bridge | 116 | Wooden | Bailey | Temporary steel | Temporary concrete | Bridge of grade 3 |
| Bridge over flow by a flood | 25 | Overflow on deck | HWL reach to girder | | | |
| One Lane Bridge | 78 | Concrete | | | | |
| Bridge length less than 7m | 83 | Temporary Bridge | Over flow Bridge | One Lane Bridge | | |
| Total | 1205 | | | | | |

# 4. TRAFFIC COUNT SURVEY

## (1) Location of Traffic Count Survey

Locations of traffic count surveys are shown in Figure 4-1.

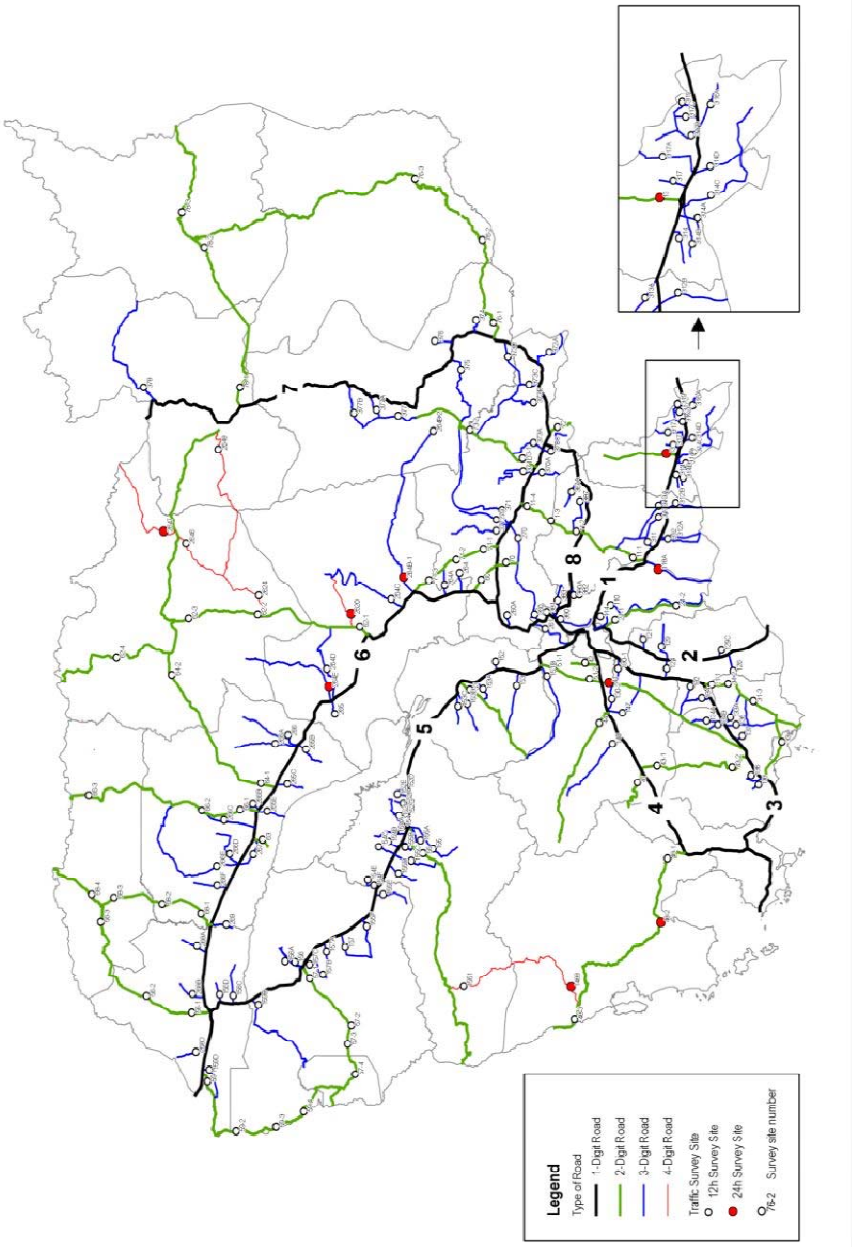
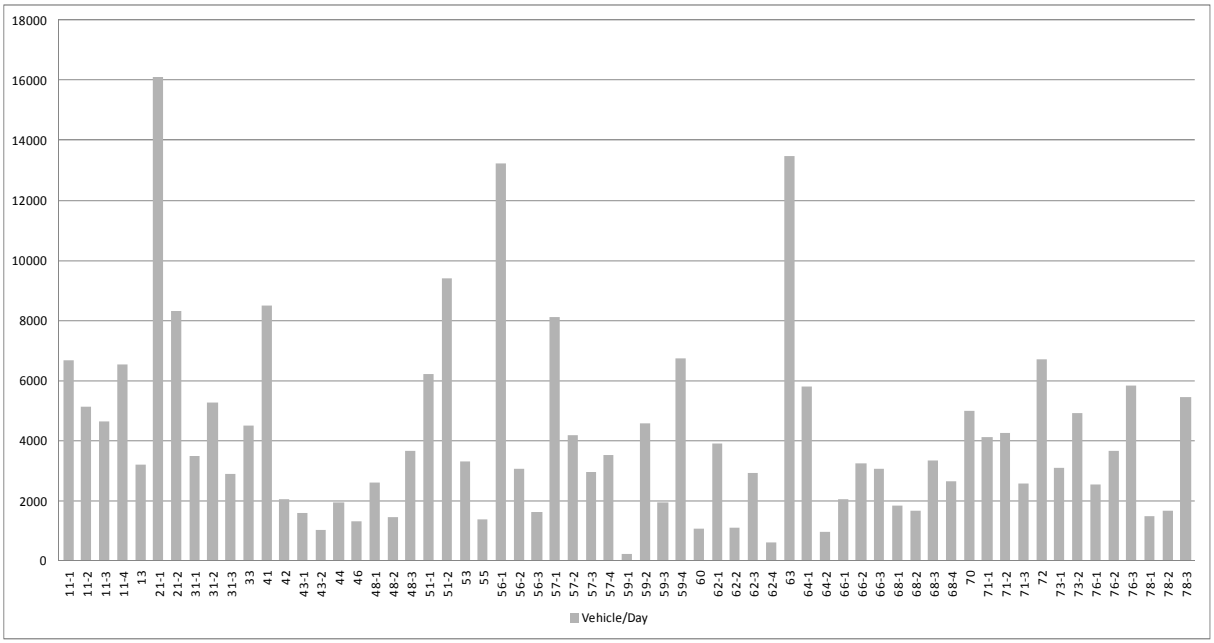



**Figure 4-1 Survey Site Locations**

### (2) Result of Survey

Daily traffic volumes are shown in Figure 4-2 and Figure 4-3.

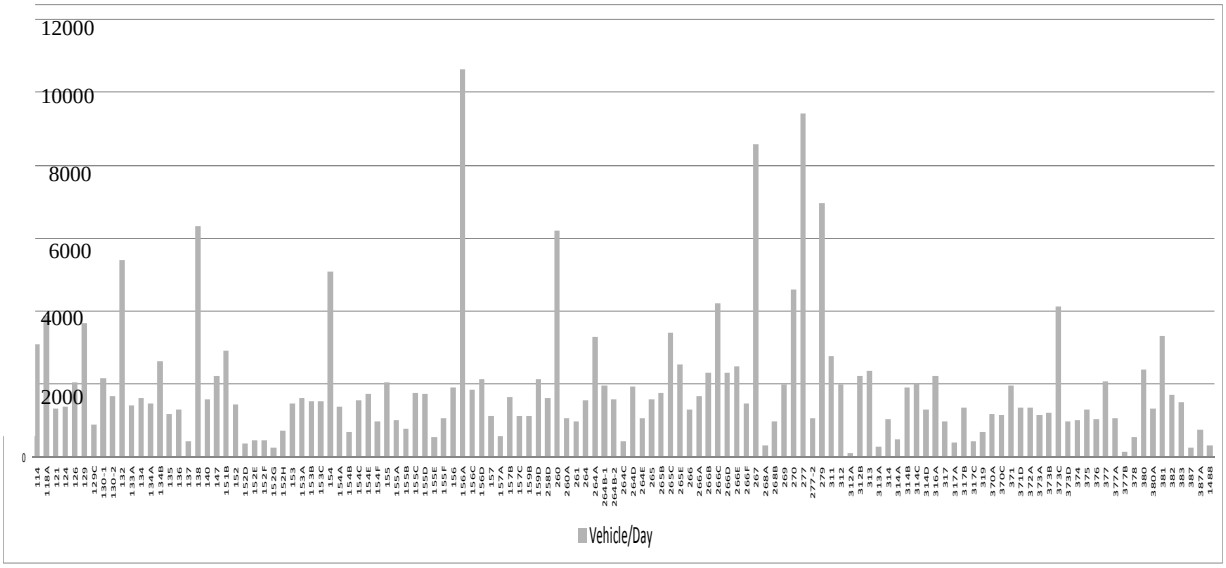
Unit: Vehicle/Day




Source: Study Team

**Figure 4-2 Daily Traffic Volume on 2-Digit Roads**

Unit: Vehicle/Day




Source: Study Team

**Figure 4-3 Daily Traffic Volume on 3-Digit Roads**

# 5. INDICATOR FOR SELECTION OF PRIORITY ROAD

The Study Team collected the data below and information as indicators for the priority of the target roads.

## 5.1 Road development plan

The Study Team collected the information on the road development plan based on three sources. These sources of information are:

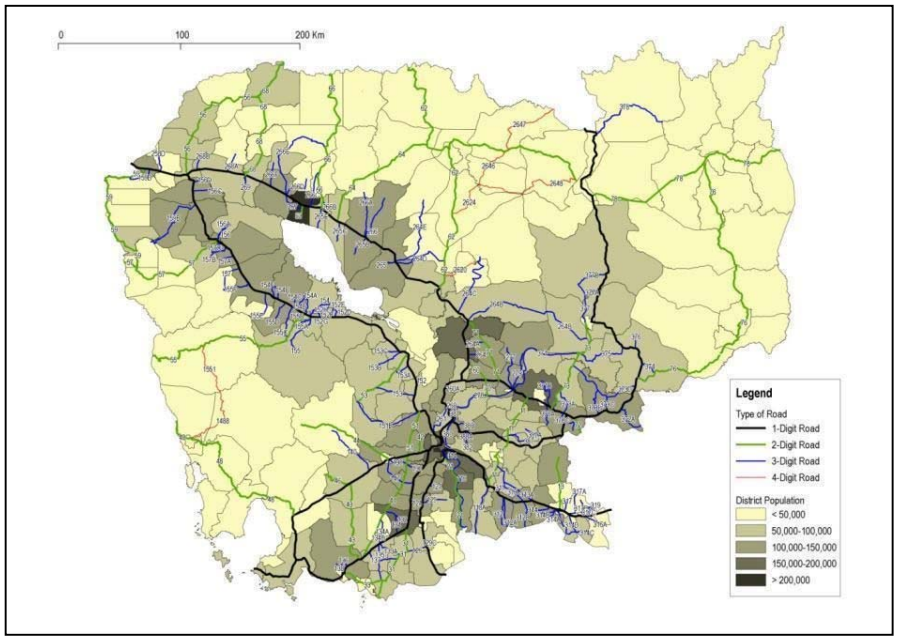
1) The master plan
2) The MPWT road development list
3) Site survey to confirm the actual condition of the road

The information on the road development plan from the 3 sources is summarized in the classification of the road development plan for the survey roads:

1) Short term
2) Medium term
3) Long term
4) Not planned

## 5.2 Population along the road

The population by district and the location of surveyed roads, as well as the number of population along the roads are shown in Figure 5-1.




Source: Study Team

**Figure 5-1 District Population and Survey Roads**

## 5.3 Characteristics of the roads

The characteristics of the survey roads are categorized into three groups and the numbers of roads in each corresponding group are as follows.

1) Road to the border: 20 roads;
2) Road for the network: 108 roads;
3) Road to dead-end: 38 roads.

## 5.4 Economy of the roadside areas

To evaluate the road priority, the economy of the roadside areas is one of the important indicators. The economy of the roadside areas is classified according to the character of the roadside vicinity which was divided into 5 categories.

1) City area
2) Industrialized area
3) Agricultural area
4) Forest or grassy plain
5) Area for natural protection

## 5.5 Number of buildings in vicinity of the bridges along the survey roads

The number of the buildings in the vicinity of the bridges along the survey roads was collected during the bridge inspection survey.

# 6. BRIDGE PLAN

## 6.1 Basic Policy of Bridge Replacement Plan

### 6.1.1 Bridge Planning

The standard design of bridge includes superstructure, substructure, foundation and approach road are determined based on the bridge inspection data collected through the survey. The type and dimension of standard design refer to the drawing collected through the "Strengthening of Construction Quality Control Project by JICA" (hereinafter referred to as the quality control project). The standard design would be planned in a way that the construction technology, and construction material suitable for the capability of Cambodian contractors.

### 6.1.2 Superstructure

#### (1) Bridge width

A bridge width with 9 m (traffic lane 7m) includes shoulder. is applied as standard bridge width for the study as shown in Figure 6-1.

Number of lane: Two (2)
Width (m) : 1.0+7.0+1.0 m

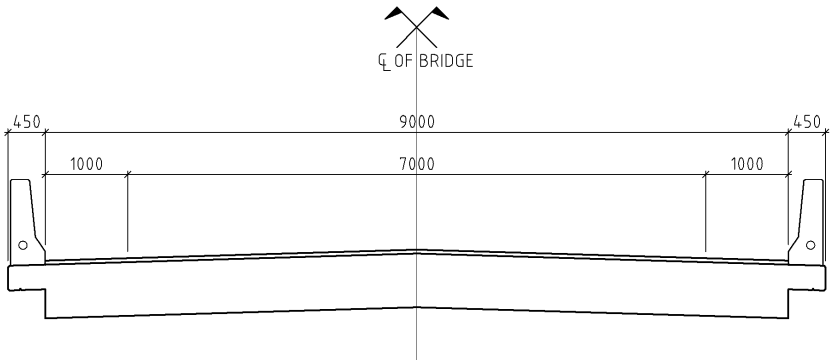



**Figure 6-1 Bridge width**

#### (2) Bridge length

Bridge length(Lp) will be determined taken in to account a data of the existing bridge in the bridge inventory. The bridge length is determined by the existing bridge length and HWL of the bridge. For instance, if the HWL will be 1.0m high above the bridge elevation, the new bridge length will be planned three times longer than existing bridge length. The expected new bridge length will be determined as follows.

Lp(m)=L*3.0 HWL=GH+1.0m (3 times of the existing bridge length L) (0.75m<HWL≤2.0m)
Lp(m)=L*2.0 HWL=GH+0.5m (2 times of the existing bridge length L) (0.25m<HWL≤0.75m)
Lp(m)=L*1.5 HWL=GH (1.5 times of the existing bridge length L) (0.0m<HWL≤0.25m)
Lp(m)=L HWL< girder under surface (HWL≤0.0m)

Where;

L : Length of existing bridge
Lp : Length of replacement bridge
HWL : High water level from the elevation of existing bridge

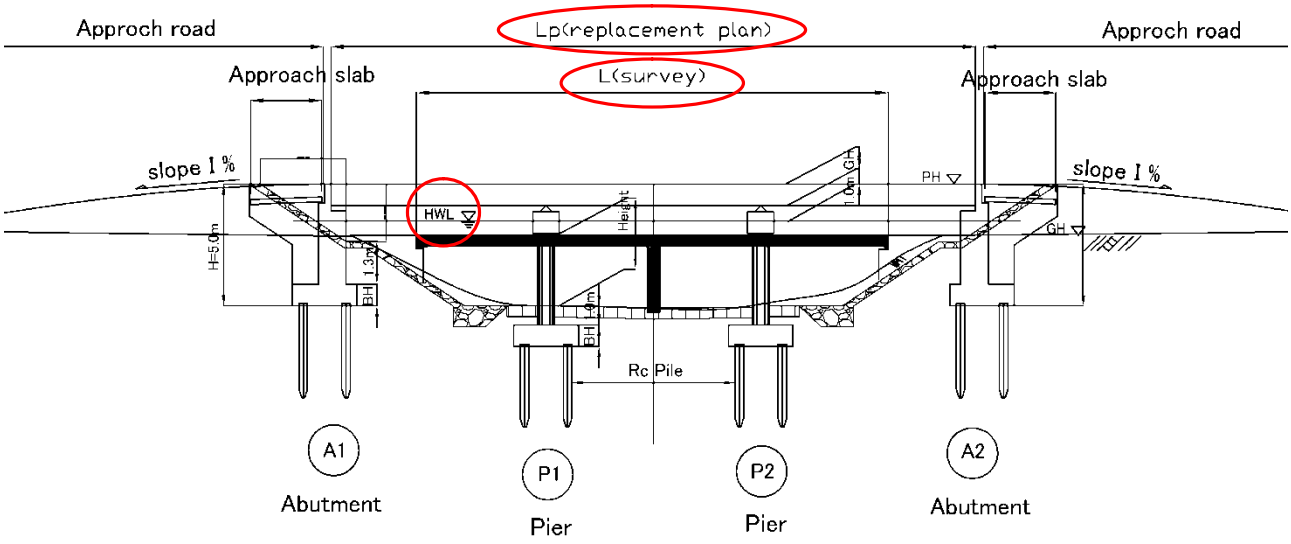



**Figure 6-2 Relationship between existing bridge and replaced bridge**

### (3) Bridge type and span length

Take into consider the capability of the local contractor, the bridge type conform to the bridge span are proposed as follows.

| | |
|---|---|
| RC Flat Slab Bridge | : L = 10 m |
| RCDG Bridge | : L = 15 m to 20 m |
| PC Hollow Slab Bridge | : L = 20 m |

Note: PC hollow slab bridge will be adopted if the construction site is near Phnom Pen (within a100km radius of the fabrication site),RCDG: Reinforced Concrete Deck Slab

**(4) Bridge accessories**

Bridge accessories would be determined based on the drawings collected through the Quality Control Project.

| | |
|---|---|
| 1) Hand Rail | : Reinforced Concrete Handrail |
| 2) Drainage | : Pipe drain |
| 3) Expansion | : Reinforced by steel at corner of slab |
| 4) Bearing | : Elastomeric bearing |
| 5) Wearing Surface | : Concrete (Asphalt : in case that the superstructure is PC Hollow Slab Bridge) |

### 6.1.3 Substructure

The dimension of substructure will be determined based on the bridge inventory data as follows.

**(1) Height of abutment (HA)**

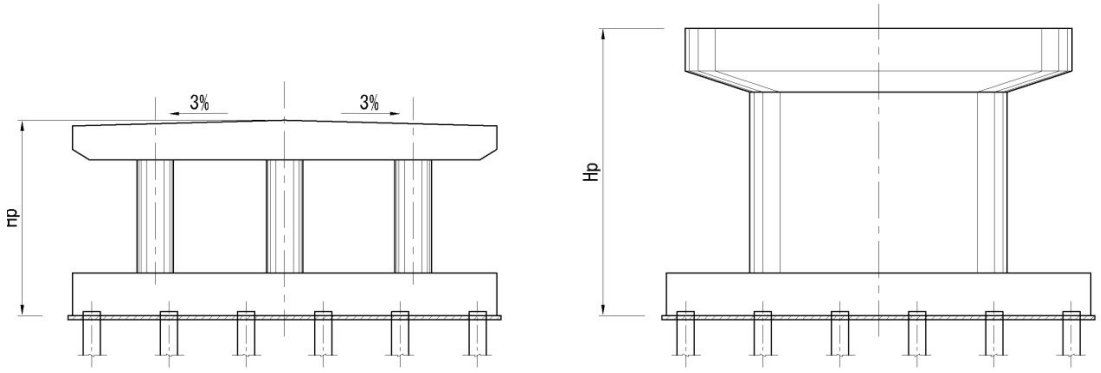
HA(m)= Maximum height(5.0m)

**(2) Height of Pier (HP)**

HP(m) = GL + HWL + AL + GRL + BH

Where;

GL : Maximum clearance of the existing bridge (survey)
HWL : High water level from the elevation of existing bridge (survey)
GDH : Girder height (planning)
AL : Allowable clearance from HWL to bottom of planned bridge (1.0m)
GRL : Distance between surfaces of ground to the top of footing (1.0m)
BH : Thickness of footing (planning)




Hp≤8.0m 8.0m<Hp

**Figure 6-3 Pier type**

### 6.1.4 Foundation

Bridge foundation type and length of pile would be determined based on the geological features at the river bed or near the river.

**Table 6-1 Foundation type**

| | River Bed condition | Foundation Type (Pile length) |
|---|---|---|
| 1 | Fine aggregate(0.35mm or less) | RC square pile (L=20m) |
| 2 | Coarse aggregate(0.35-2mm) | RC square pile (L=15m) |
| 3 | Gravel(2-75mm) | RC square pile (L=10m) |
| 4 | Boulder(75-300mm) | Spread foundation |
| 5 | Rock(More than 300mm) | Spread foundation |

### 6.1.5 Approach Road

The length of the approach road are determined based on the geographical feature at the bridge site and set as follows.

**(1) Length of approach road**

Flat plane

$L_F(m)=(PH-GH)x200/I$

I : Slope 4.0%

Gentle hill

$L_G(m)=1/2L_F$ (m)

Steep mountain

$L_S(m)=0.0$

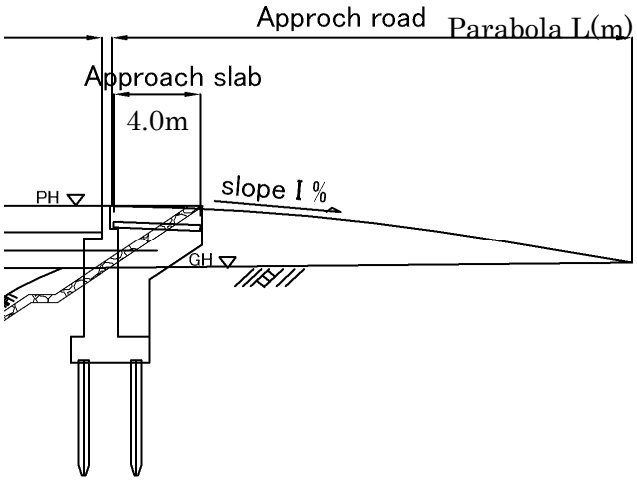



**Figure 6-4 Approach road**

**(2) Length of approach slab**

LL=4.0m

**(3) Width of approach road**

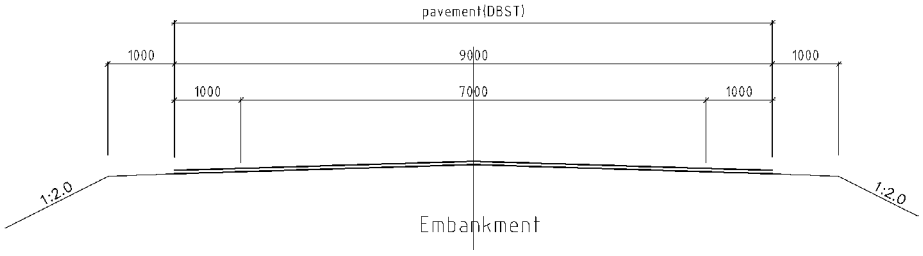



**Figure 6-5 Standard width of approach road**

### 6.1.6 Protective and preventive measures

As a result of site investigation in February 2012, serious damages or failures of bridges have been found caused by scouring around bridge abutments and piers. They need to undergo proper measures to recover from the harmful effects caused by the flooding of 2011 and it is necessary to reinforce durability of the slope protection. Gabion mattress is applied for a score prevention and slope protection in this study.

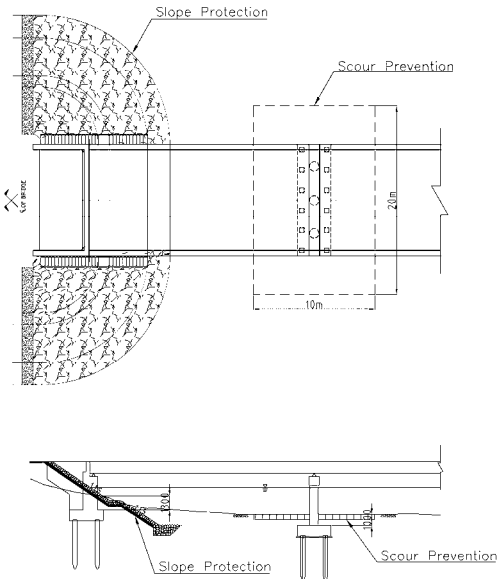



**Figure 6-6 Slope protection and scour prevention**

### 6.1.7 Temporary detour during the construction of new bridge

Case1: Height of the road surface from river bed is less than 5m

Embankment is constructed beside a new bridge as detour

Case2: Height of road surface from river bed is larger than 5m

Temporally bridge is constructed beside a new bridge as a detour

### 6.1.8 Standard Drawings

General drawings of each type of bridges are shown in the Figure 6-7 to Figure 6-9.

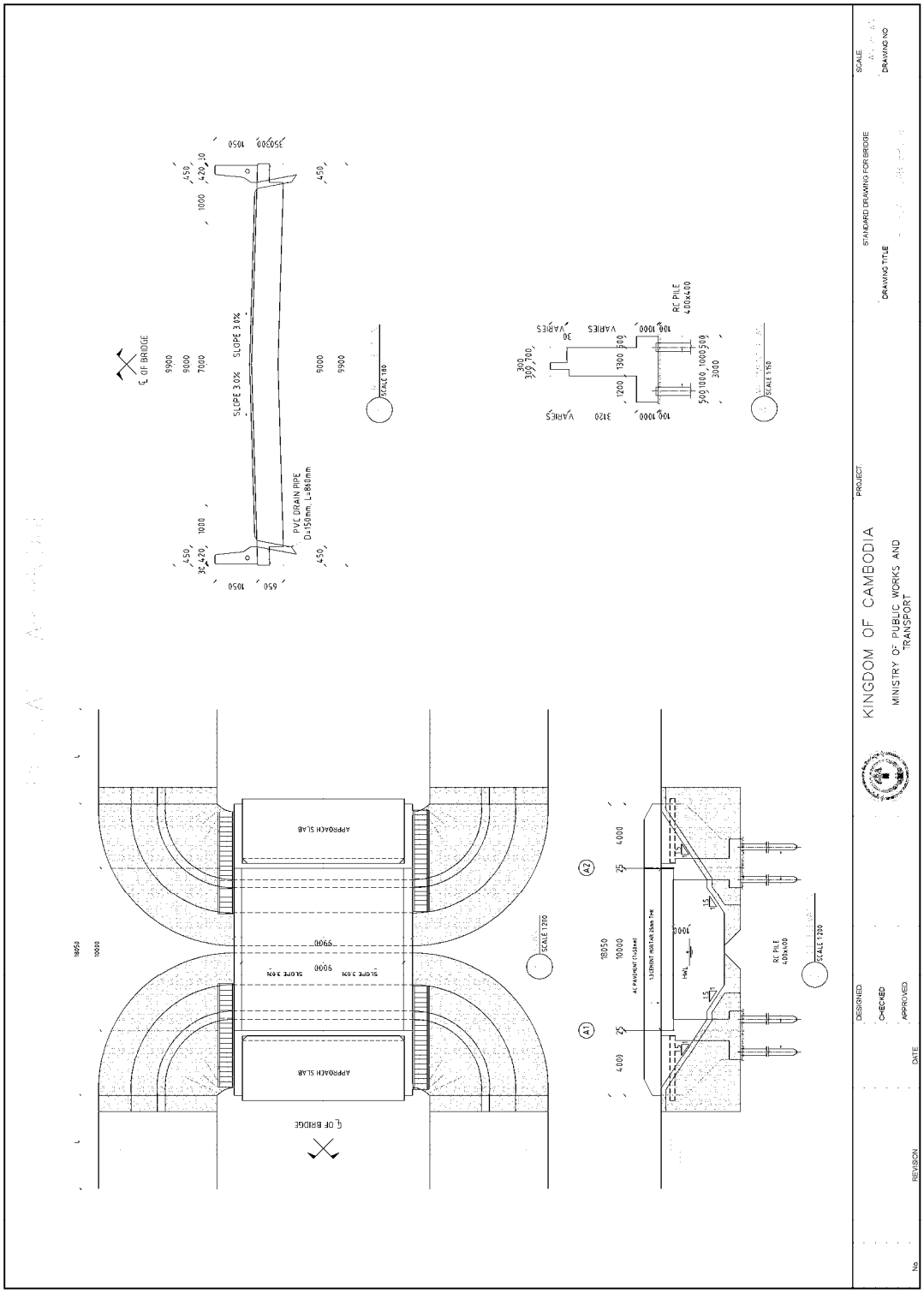



**Figure 6-7 RC Flat Slab Bridge**

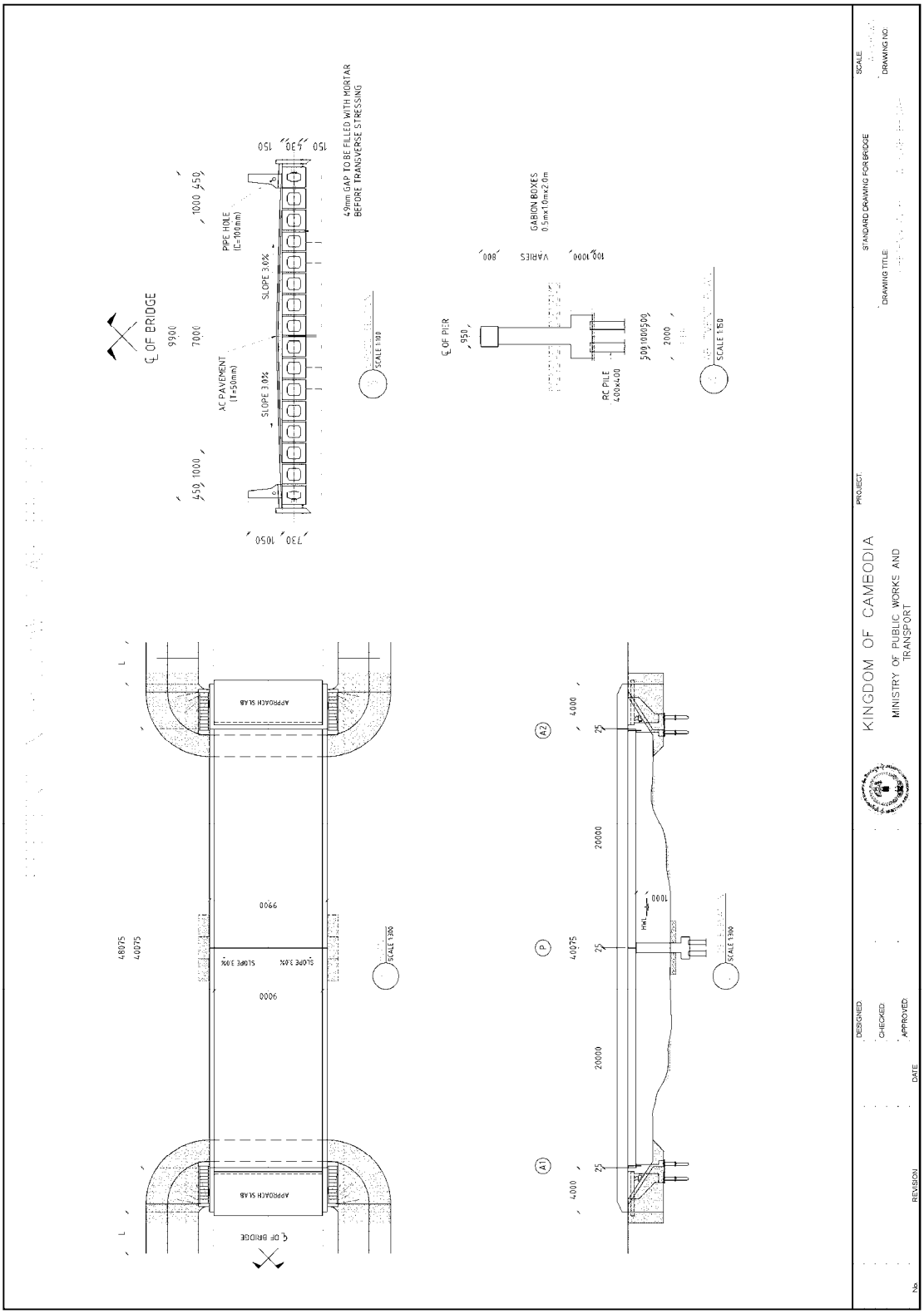



**Figure 6-8 RCDG Bridge**

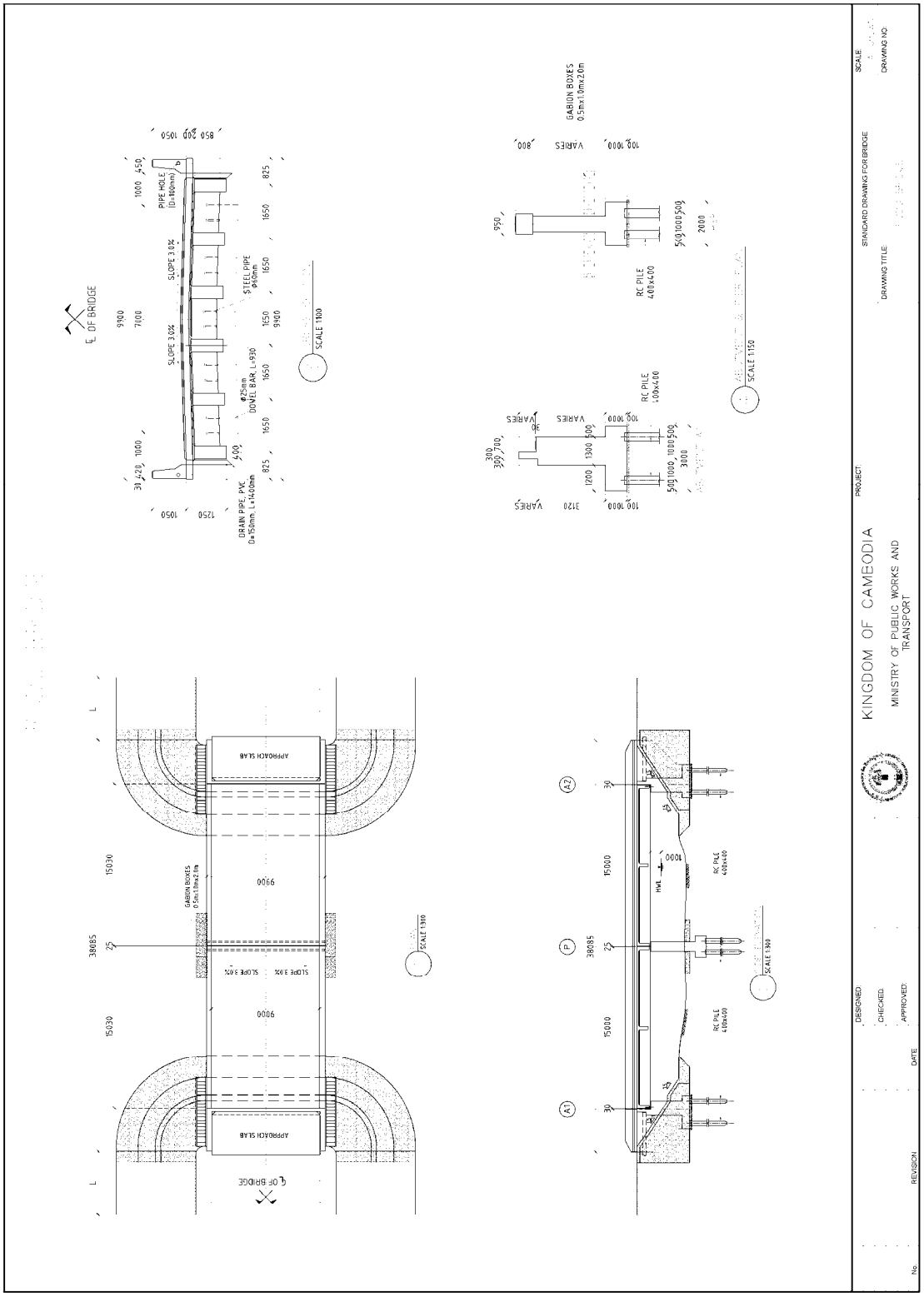



**Figure 6-9 Pretension PC Hollow Slab Bridge**

## 6.2 Target Bridges to be Replaced with First Priority

### (1) List of Bridges on the Group1 and Group2

The selected 47 bridges are located along NR1 and NR7 are shown in Figure 6-10. An example of the dimensions and properties of bridges are listed in Table 6-2.

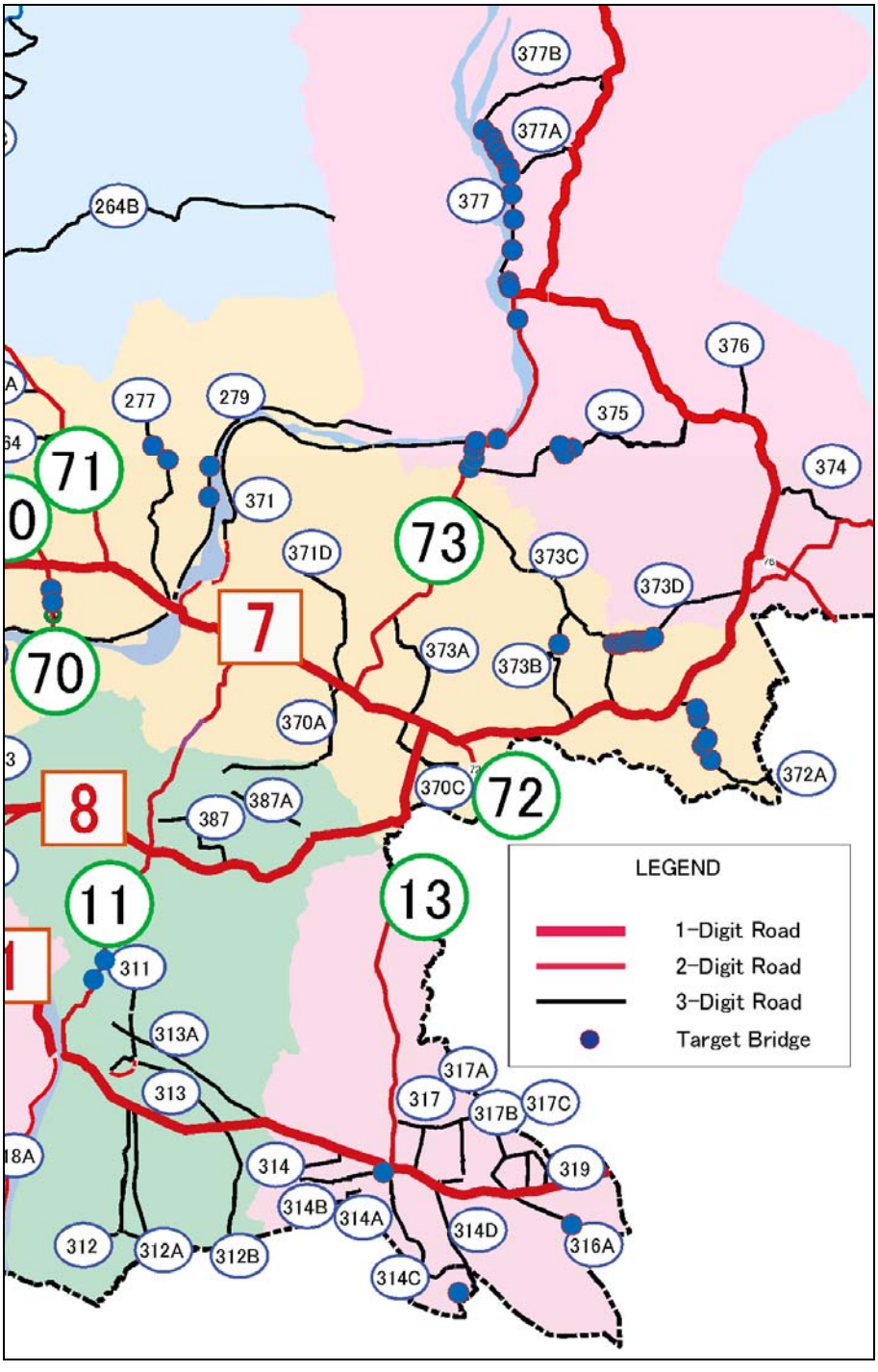



**Figure 6-10 Location of the Bridges**

**Table 6-2 Dimensions and Properties**

| | | | |
|---|---|---|---|
| Road No. | 277 | Coordinate | |
| Bridge No. | 3 | North Latitude | 12˚ 14' 17.4" |
| Distance from PP [1] | 95.13km | East Longitude | 105˚ 27' 10.6" |
| **Replacement Bridge** | | **Existing Condition of the Bridge** | |
| **Superstructure** | | | |
| Bridge Type | PC Hollow | Bridge Type | Bailey |
| Bridge Length | 45.0m | Bridge Length | 27.0m |
| No. of Span | 3 | Span Length | 27.0m |
| Width | 9.90m | Width | 5.10m |
| Grand Surface [2] | 2.73m | Particle Size | Gravel |
| **Pier** | |  | |
| Pier Type | Single Column | | |
| Height | 10.0m | | |
| Foundation Type | Pile ($\phi$ 500) | | |
| Pile Length | 10.0m | | |
| **Abutment** | | | |
| Abutment Type | Inverted-T | | |
| Height | 5.0m | | |
| Foundation Type | Pile(□400*400) | | |
| Pile Length | 10.0m | | |

| | | | |
|---|---|---|---|
| Road No. | 314C | Coordinate | |
| Bridge No. | 1 | North Latitude | 11˚ 04' 41.9" |
| Distance from PP [1] | 110.31km | East Longitude | 105˚ 48' 10.6" |
| **Replacement Bridge** | | **Existing Condition of the Bridge** | |
| **Superstructure** | | | |
| Bridge Type | RCDG | Bridge Type | Bailey |
| Bridge Length | 70.0m | Bridge Length | 69.0m |
| No. of Span | 4 | Span Length | 24.0+21.0+24.0 m |
| Width | 9.90m | Width | 5.40m |
| Grand Surface [2] | 1.23m | Particle Size | Fine aggregate |
| **Pier** | |  | |
| Pier Type | Multi Column | | |
| Height | 6.0m | | |
| Foundation Type | Pile(□400*400) | | |
| Pile Length | 20.0m | | |
| **Abutment** | | | |
| Abutment Type | Inverted-T | | |
| Height | 5.0m | | |
| Foundation Type | Pile(□400*400) | | |
| Pile Length | 20.0m | | |

*Notes : 1) Distance from Phnom Penh to the bridge construction site

2) Height of new road surface from existing road surface

**(2) Dimension of the Target bridges**

Among 47 bridges, two bridges are shown as examples and they are shown in figure 6-11 to 6-12 . They are Bridge No.3 on PR277, Bridge No.1 on PR314C respectively.

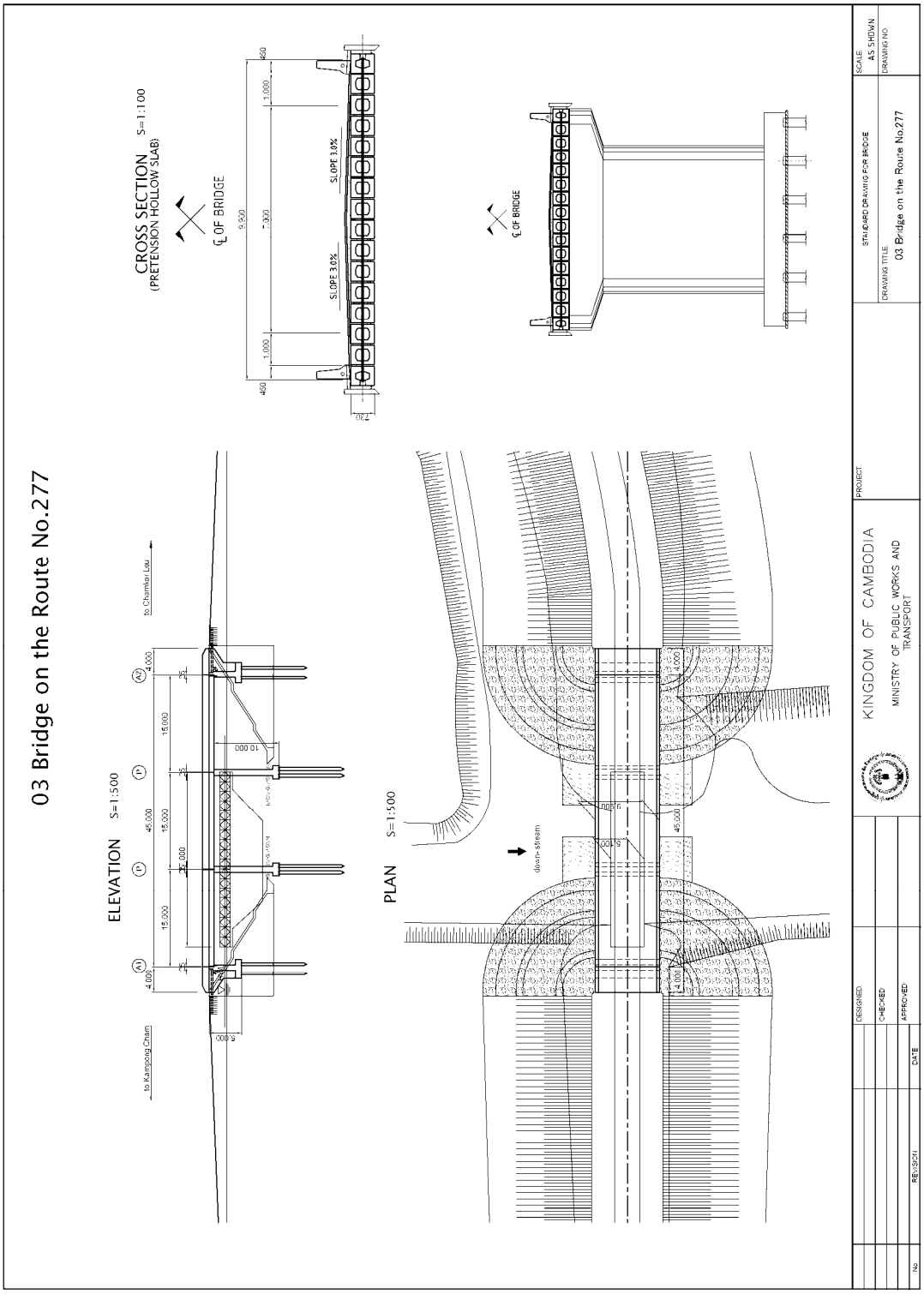



**Figure 6-11 Plan of No3 Bridge on the Route No. 277**

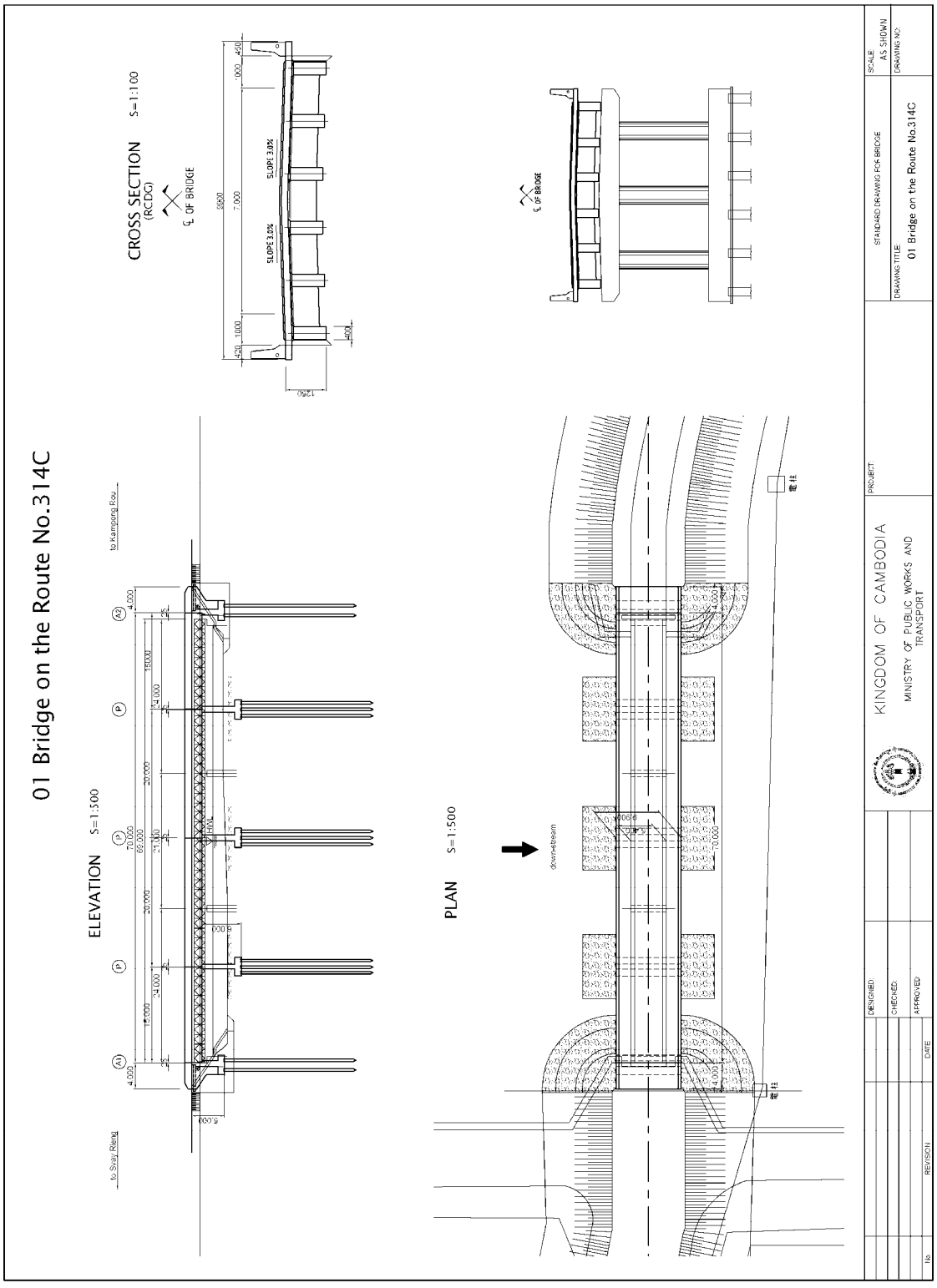



**Figure 6-12 Plan of No1 Bridge on the Route No. 314C**

## 6.3 Construction Plan of the Bridge

### 6.3.1 Construction Method of the Bridges

Bridges being assumed as new bridge to be replaced in the Study are consisted of reinforced concrete (RC) bridges with span lengths ranging from 10 to 20 metres and pre-stressed concrete (PC) bridges. Since these bridges are commonly constructed in Cambodia, so that ordinary construction methods are assumed. The ordinary construction methods applied in this study are as follows.

**(1) RC bridges**

1) Construction on scaffolding (RC Flat Slab Bridge)
2) Girder erection by truck-crane (RCDG Bridge)

**(2) PC bridges**

1) Girder erection by truck-crane

### 6.3.2 Construction Schedule of the Bridges

An example of construction schedule is shown in Table 6-1, which assumes an RC bridge with a bridge length of 30 metres (=2x15 metres), two abutments of pile foundation and one pier of pile foundation. Estimated construction duration is 15.5 months.

## 6.4 Cost Estimation of Bridges

### 6.4.1 Basis of Bridge Cost Estimation

Cost estimation is carried out based on the cost information of the bridges which were funded by the Government. These bridges were constructed by Road Infrastructure Department Bridge Unit (Hereinafter referred to as RID Bridge Unit) and the HEC. They are division for bridge construction funded by the Government of Cambodia. The administration and supervising fee are not included in the construction cost.

### 6.4.2 Construction Costs of the Bridges on the Group1 and Group2

Material quantities of a newly constructed bridge are calculated in accordance with the standard design. Quantities of concrete and rebar are calculated and listed in the standard design. These quantities are used for cost estimation of the target bridges.

Items for analyzing the construction costs for new bridges are as follows.

**(1) Bridges**

1) Concrete
2) Rebar
3) Superstructure miscellaneous, such as bearings
4) Expansion joints, etc
5) Substructure miscellaneous, such as earthwork, scaffoldings, false work, signboards, etc

**(2) Approach road**

1) Earthwork
2) Pavement

**(3) Revetment and river bed protection**

Revetment and river bed protection are calculated based on the gabion cost per square metre derived from the cost information.

Table 6-3 shows construction costs of the bridges on the Group1 and 2 estimated by the unit costs.

**Table 6-3 Construction Costs of the Bridges**

| Road No. | Bridge No. | Cost (USD) | Sub Total (USD) | Road No. | Bridge No. | Cost (USD) | Sub Total (USD) |
|---|---|---|---|---|---|---|---|
| 11 | No.2 | 2,213,281 | 4,233,259 | 373D | No.1 | 223,151 | 3,301,477 |
| | No.3 | 2,019,978 | | | No.2 | 332,200 | |
| 70 | No.1 | 2,074,419 | 4,014,307 | | No.3 | 284,420 | |
| | No.2 | 1,939,888 | | | No.4 | 284,980 | |
| 73 | No.4 | 3,568,084 | 14,441,352 | | No.5 | 381,320 | |
| | No.5 | 1,059,957 | | | No.6 | 700,781 | |
| | No.6 | 1,319,739 | | | No.7 | 265,982 | |
| | No.7 | 1,163,920 | | | No.9 | 270,778 | |
| | No.8 | 3,273,284 | | | No.10 | 280,758 | |
| | No.16 | 4,056,368 | | | No.12 | 277,107 | |
| 277 | No.3 | 1,076,648 | 1,447,291 | 375 | No.2 | 824,145 | 1,773,503 |
| | No.4 | 370,643 | | | No.3 | 328,309 | |
| 279 | No.7 | 3,170,040 | 3,170,040 | | No.4 | 621,049 | |
| 314C | No.1 | 1,033,501 | 1,033,501 | 377 | No.1 | 1,049,340 | 13,371,630 |
| 314D | No.1 | 508,472 | 508,472 | | No.2 | 1,375,449 | |
| 316A | No.1 | 591,837 | 591,837 | | No.3 | 1,262,579 | |
| 372A | No.1 | 582,900 | 2,452,042 | | No.4 | 2,183,318 | |
| | No.2 | 510,055 | | | No.5 | 1,471,081 | |
| | No.3 | 517,637 | | | No.6 | 596,511 | |
| | No.4 | 324,716 | | | No.7 | 1,000,005 | |
| | No.5 | 516,734 | | | No.8 | 370,706 | |
| 373B | No.1 | 316,660 | 316,660 | | No.9 | 838,725 | |
| | | | | | No.10 | 1,437,826 | |
| | | | | | No.11 | 893,045 | |
| | | | | | No.12 | 893,045 | |
| Total | | | | 50,655,371 | | | |

Source: Study Team

# 7. ECONOMIC EVALUATION OF THE PROJECT

## 7.1 Methodology

Economic analysis was carried out through economic cash flow analysis. The economic analysis is a comparative analysis between benefits and costs relative to the project.

Cost is the economic cost that includes construction cost and maintenance cost without subsidy or taxes. Benefit includes benefit of time saving and benefit of vehicle operating cost saving.

The figure below shows the flow of an economic evaluation,

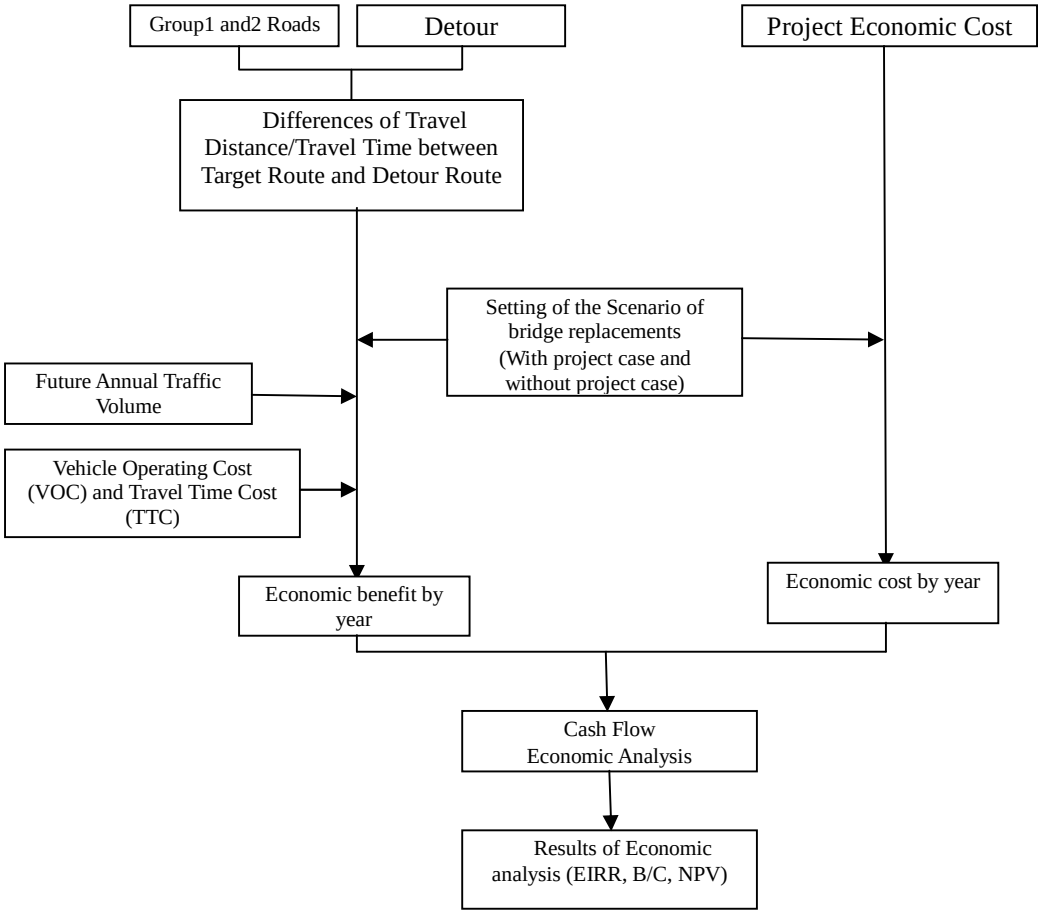


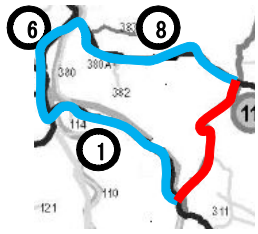
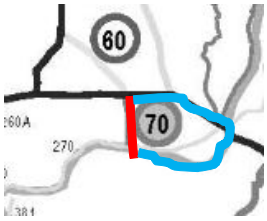
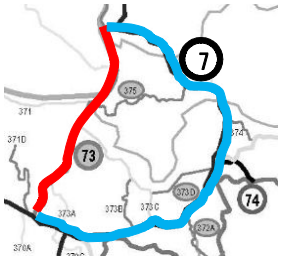
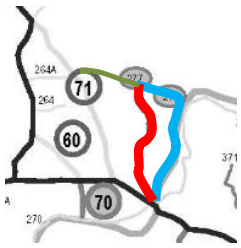
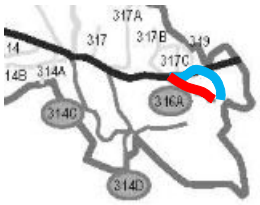
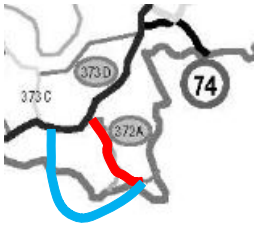
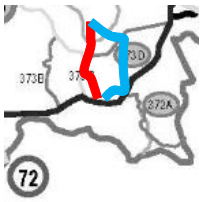
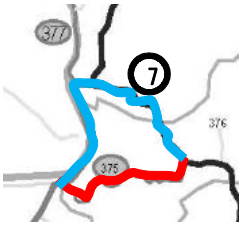
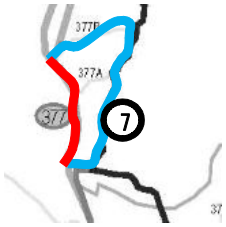

**Figure 7-1 Procedure for Economic Analysis**

## 7.2 Assumptions for Economic Analysis

### (1) Roads of Group1 and Group2, and Detours for the Evaluation

The economic analysis was carried out for 13 roads of Group 1 and 2

Detours of the roads of Group 1 and 2 are shown in the Figure 7-2.

| 11 | 70 | 73 |
|---|---|---|
|  |  |  |
| 277 | 279 | 314C |
|  |  |  |
| 314D | 316A | 372A |
|  |  |  |
| 373B | 373D | 375 |
|  |  |  |
| 377 | | |
|  | Legend:<br>: Target Road<br>: Detour<br>: Road Number | |

Source: Study Team

**Figure 7-2 Detours for 13 Roads**

**(2) Difference of Travel Distance and Travel Time between Target Routes and Detours**

Differences of travel distance and travel time between target routes and detours are calculated using the results of the travel speed survey. The differences are shown below.

Difference of Travel Distance (km) = Detour Length (km) - the Road Length (km)

Difference of Travel Time (hour) = Travel Time of Detour (hour) – Travel Time of the road(hour)

It was assumed the differences of distances and the times between the roads of Group1 and 2, and the detour will be basically the same in the future. The differences are used as the distance and time saving for the economic analysis.

**Table 7-1 Difference of Travel Distance and Travel Time between Target Routes and Detours for Economic Analysis**

| | Road Number | Travel Distance Difference (km) | Travel Time Difference (hour) |
|---|---|---|---|
| 1 | 11 | 39.0 | 1.31 |
| 2 | 70 | 33.5 | 0.69 |
| 3 | 73 | 82.6 | 1.25 |
| 4 | 277 | 27.0 | 0.67 |
| 5 | 279 | 18.9 | 0.65 |
| 6 | 314C | 5.5 | 0.03 |
| 7 | 314D | 1.4 | 0.04 |
| 8 | 316A | 3.7 | 0.04 |
| 9 | 372A | 24.9 | 0.24 |
| 10 | 373B | 22.3 | 0.19 |
| 11 | 373D | 21.7 | 0.15 |
| 12 | 375 | 50.0 | 0.51 |
| 13 | 377 | 50.4 | 0.55 |

Source: Study Team

**(3) Setting of the Scenario of Bridge Replacements (“With project case” and “Without project case”)**

1) Replacement Plan and Evaluation Period for NR11, NR70, NR73, PR279

a) With project case

First replacement start time: April 2014.

If two or more bridges are on the roads, each replacement will start one year after the previous bridge replacement started. Additional bridges replacements will not start at the same time.

Construction period: 26months

There is no impassable period.

b) Without project case

First time of bridge becoming impassable: November 2018

The route will become passable 14 months after it became impassable

First bridge replacement start time: November 2019.

If two or more bridges are on the roads, it is assumed that another bridge will become impassable every two years and not more than one bridge will be impassable at any given time.

Construction period: 26months

2) Replacement Plan and Evaluation Period for PR277, PR372A, PR373B, PR373d, PR375, PR377, PR314C, PR314D,PR316A

a) With project case

First replacement start time: April 2014.

If two or more bridges are on the roads, each replacement will start one year after the previous bridge replacement started.

Construction period: 19months

There is no impassable period.

b) Without project case

First time of bridge becoming impassable: November 2018

The route will become passable 14 months after it first became impassable

First bridge replacement start time: November 2019

If two or more bridges are on the roads, it is assumed that another bridge will become impassable every two years and not more than one bridge will be impassable at any given time.

Construction period: 19months

### (4) Daily Traffic to Annual Traffic Volume

The evaluation period is assumed to be 30 years from 2018 to 2047 as the service life of the projects. The expansion factor from daily traffic to annual traffic volume is assumed to be 340 days per year considering weekly variation of the traffic volume.

**(5) Discount Rate**

Twelve percent is assumed as the discount rate in Cambodia.

**(6) Future Traffic Volume**

Traffic volume is basic data for the estimation of the benefit of the project. The traffic demand forecasts for the roads have been carried out with a simplified method considering the traffic volume and the growth ratios of the number of registered vehicles. Future traffic annual volumes were estimated by the formula below.

Future Annual Traffic Volume = Daily Traffic Volume of Previous Year x Annual Growth Rate of Registered Vehicles x 340 (days)

## 7.3 Economic Cost Estimation

Economic costs of construction are shown below.

a) Bridge construction cost on NR11, NR70, NR73 and PR279

USD 1,576,000/Bridge

b) Bridge construction cost on PR277, PR372A, PR373B, PR373D, PR375, PR377, PR314C, PR314D and PR316A

USD 583,000/Bridge

## 7.4 Benefit Estimation

Travel distance cost saving and travel time cost saving were considered as benefits for the economic analysis. Vehicle Operating Costs (VOC) and Travel Time Costs (TTC) were estimated based on the data from the NR5 report[1].

Benefit will be calculated by the reduction of travel distance and travel time as an outcome of a Project in general, however the maintenance project including bridge replacement will not create any reduction of travel distance or travel time. On the other hand, all the traffic on a road will be stopped and forced to use a detour when a bridge on the road is closed due to significant damage. An unbearable loss from increasing travel distance and travel time will be incurred by using a detour when the road is closed. Loss arising from increase of travel distance and travel time by closing the bridges is shown in Table 7-2.

The loss by closing the bridges is unbearable compared with the replacement cost, so that the projects to reopen the roads are absolutely essential. For this reason, benefit of the project is considered to be the difference between preventive maintenance and breakdown

[1] Preparatory Survey for National Road No.5 Rehabilitation Project In the Kingdom of Cambodia (JICA, 2012)

maintenance. Definitions of the breakdown maintenance and preventive maintenance are as follows:

1) Breakdown maintenance

A bridge is not replaced nor maintained until the bridge is closed to traffic. The road will be closed until a detour alongside of the existing bridge can be established.

2) Preventive maintenance

A bridge is replaced before the bridge is closed to traffic.

**Table 7-2 Construction Cost, and Loss (Benefit) Occurred by Closing of Bridges**

| Road No. | Cost (1,000 USD) | Loss (Benefit) (1,000USD) | B/C |
|---|---|---|---|
| 11 | 2,168 | 147,921 | 68.2 |
| 70 | 2,168 | 54,366 | 25.1 |
| 73 | 5,274 | 203,656 | 38.6 |
| 277 | 830 | 6,434 | 7.8 |
| 279 | 1,145 | 55,123 | 48.1 |
| 314C | 439 | 1,717 | 3.9 |
| 314D | 439 | 807 | 1.8 |
| 316A | 439 | 1,975 | 4.5 |
| 372A | 1,771 | 4,369 | 2.5 |
| 373B | 439 | 8,327 | 19 |
| 373D | 2,775 | 14,087 | 5.1 |
| 375 | 1,180 | 16,755 | 14.2 |
| 377 | 3,043 | 38,299 | 12.6 |

Source: Study Team

## 7.5 Economic Analysis

The economic indicators shown below were calculated by economic analysis.

1) Economic Internal Rate of Return (EIRR)
2) Benefit – Cost Ratio (B/C)
3) Net Present Value (NPV)

Results of the economic analysis are shown below.

**Table 7-3 Results of Economic Analysis**

| | Road Number | EIRR | B/C | NPV (1,000 USD) |
|---|---|---|---|---|
| 1 | 11 | 88.2% | 10.1 | 19,695 |
| 2 | 70 | 53.0% | 4.0 | 6,602 |
| 3 | 73 | 94.6% | 14.3 | 70,018 |
| 4 | 277 | 19.2% | 1.3 | 289 |
| 5 | 279 | 54.5% | 3.8 | 3,163 |
| 6 | 314C | Negative | 0.4 | -264 |
| 7 | 314D | Negative | 0.1 | -374 |
| 8 | 316A | Negative | 0.4 | -257 |
| 9 | 372A | 10.4% | 0.9 | -144 |
| 10 | 373B | 26.1% | 1.7 | 298 |
| 11 | 373D | 31.2% | 2.7 | 4,683 |
| 12 | 375 | 42.6% | 3.4 | 2,815 |
| 13 | 377 | 61.0% | 7.2 | 18,915 |

Source: Study Team

# 8. STUDY ON THE INFORMATION SYSTEM

## 8.1 Existing condition of Bridge Maintenance

A periodical bridge inspection per two years, a visual inspection per month and ad hoc inspection based on the information from local people or road users are carried out by the DPWT. The budget for bridge repair is prepared by the MEF through the MPWT. The practical bridge repairs are carried out by RID Bridge Unit in the DPWT. Relevant organization in the Cambodia for bridge maintenance and their functions are shown in Figure 8-1.

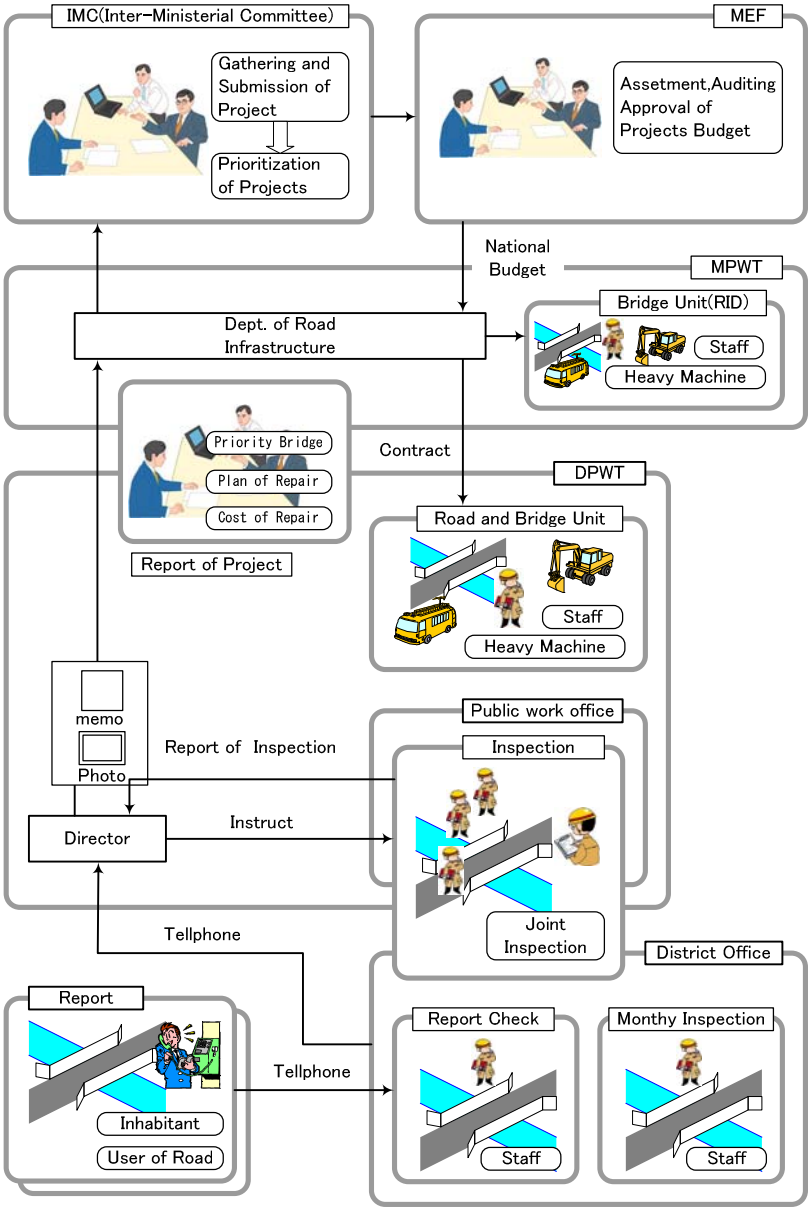



**Figure 8-1 Organization relevant to Bridge Maintenance in Cambodia**

## 8.2 Road Information in the Cambodia

### (1) Information System for road management in the Cambodia

Basic structural information of bridges is handled by several information systems, however there is not detailed information necessary for systematic bridge maintenance. The Road Management Systems in the Cambodia are shown in Table 8-1.

**Table 8-1 Road Management System in the Cambodia**

| Department | System | Description |
|---|---|---|
| RID | — | There is no Road management system |
| HEC | RAMP | Development of road asset management system is under study. Management for road surface is the main objective of the system however basic structural information of bridge and culvert and their conditions are also planned to record in the system |
| PWRC (Infrastructure) | Document Data Base System | Document file including design standard, regulation, design document and as build drawing which accumulated in the MPWT are converted into image data. The data is possible to be searched within the system. |
| PWRC (Topographic) | GIS System | The system was developed through JICA project in 2003. Basic bridge information including road number, location of bridge and structure type are recorded in the system, however the data is not updated to the present. |

### (2) Outline of the Road Management System in the Cambodia

1) Outline of Road Asset Management Project (RAMP)

The RAMP is planned to be developed by the HEC. The system will consist of road pavement management function (HIMS), road investigation system (ROMDAS), System to measure the pavement deflection (FWD) and Basic Map System (ArcGIS) based on the HDM4 (Pavement management system) offer by the World Bank and ADB.

In addition to the inventory of pavement, the system administrates the other inventory data and rank of deterioration of bridges and culverts. The ranks of deterioration for bridges and culverts are recorded as Good, Fair and Poor. Grade of deterioration and total condition of Slab, handrail, guardrail, abutment, pier, expansion joint, traffic sign and bank protection of bridge will be evaluated. , and wall and drainage condition will be evaluated for culverts.

2) Circumstances of the RAMP

The RAMP is managed by the Road Data Collection Management Unit (RDCMU) established in the MPWT. According to the report issued on March 2012 by the RAMP, members of the relevant divisions of the MPWT were transferred to the RDCMU. However the relationship and responsibilities between the divisions are not clear taken into consider the flow of road maintenance activities. The RDCMU is a special division for collection and management of information and has two major objectives, one is information management and other is site survey to collect inventory of road facilities. Road and bridge engineers work part time and they collect, administer and manage information for road management. Therefore the engineers from the RID and the DPWT will take charge for the new division which has responsibility for the maintenance of roads and bridges. There is a group in the PWRC which handles topographic data and updated road information on the GIS and integration of the group with the new division shall be studied.

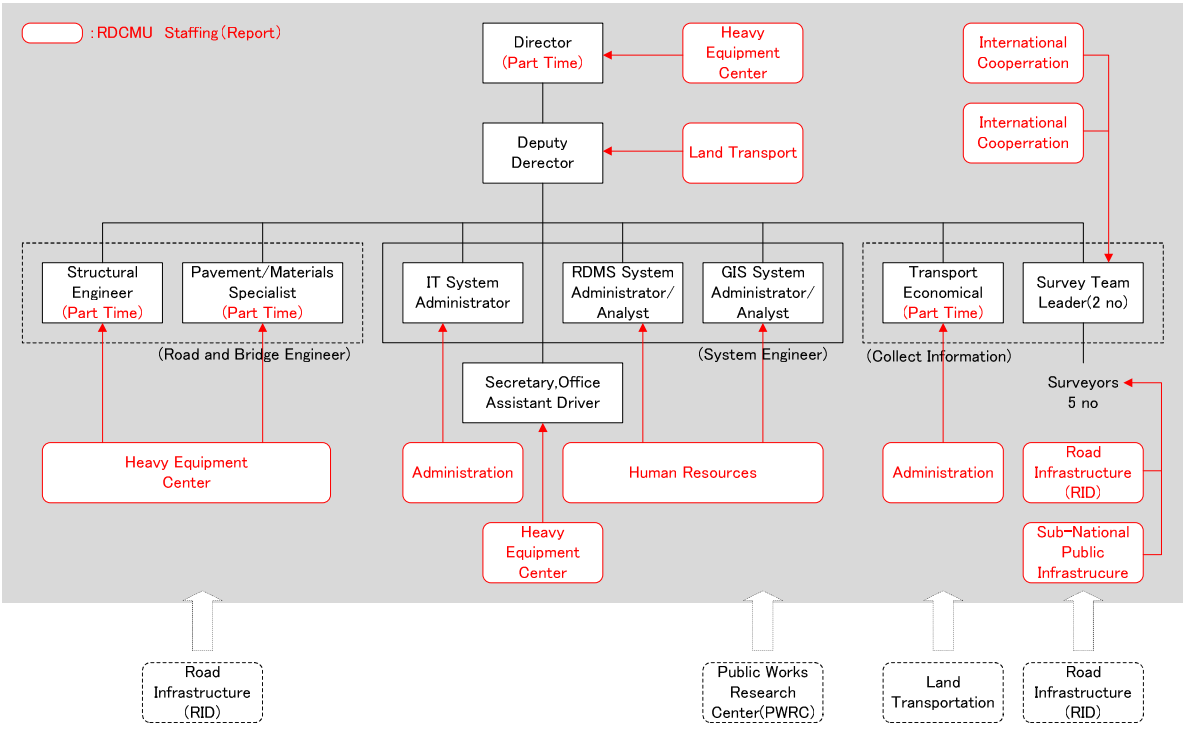



**Figure 8-2 Organization of the RDCMU for the RAMP**

3) Document Data Base System

a. Outline of the System

The document Data Base System is developed through the quality control project, and the PWRC, the RID, the HEC, the DPWT are cooperating for the development of the system. The documents including design standards, specifications, reports of project by donor countries and as-built drawings are managed by the system.

b. Items managed by the system

Image file, word file, excel file and compressed file are managed by the system. The system is already operated sufficiently and is now collecting data from the divisions concerning the bridge construction.

c. System composition

Utilization of the system is limited to registration and access to the document data. Data registration and access to the data shall be operated directly on the web server because the Local Area Network (LAN) system is not yet provided in the MPWT. However, a system is developed to make the staff in the MPWT utilize the system through network. It is possible to restrict the system users by user authentication system on a display when the system starts.

4) GIS System

The GIS system is developed by the topographic section in the PWRC. Road information and bridge information are included in the system however the bridge information has not been updated since the information of bridges entry through JICA project in 2003. ArcViewGIS3.3 introduced through JICA project is utilized for the GIS system. The information of the GIS cannot be contacted through network therefore limited staff are able to utilize by the copy of the data.

## 8.3 Information Management for Bridge Maintenance

### (1) Existing bridge maintenance activity and flow of information

Bridge information shall be collected and accumulated in the database for repair or replacement of bridges in near future s It is important that the structural data and inspection data shall be accumulated efficiently taking into consider the flow of the bridge maintenance activities. Entry and update of the bridge data will be carried out on three occasions, 1. Just after the bridge is constructed, 2. When bridge is inspected, and 3. Just after the bridge is repaired. Entry and update of the bridge information shall be unified into a division in charge because bridge information in different status is managed by several divisions in the Cambodia.

### (2) Management of information from bridge inspection

Bridge information is collected based on the inspection sheet by the site survey in this project The bridge information collected and stored in the database is converted into a list to make the reference of the information simple. Inspection sheets used in this project are shown in Table 8-2 and Table 8-3. The process by which bridge information in the database is converted in to bridge list is shown in Figure 8-4. The bridge information shall be identified by its coordinates and the coordinates are converted into Google earth map and it is shown in Figure 8-5.

**Table 8-2 Bridge Inspection Sheet (1)**

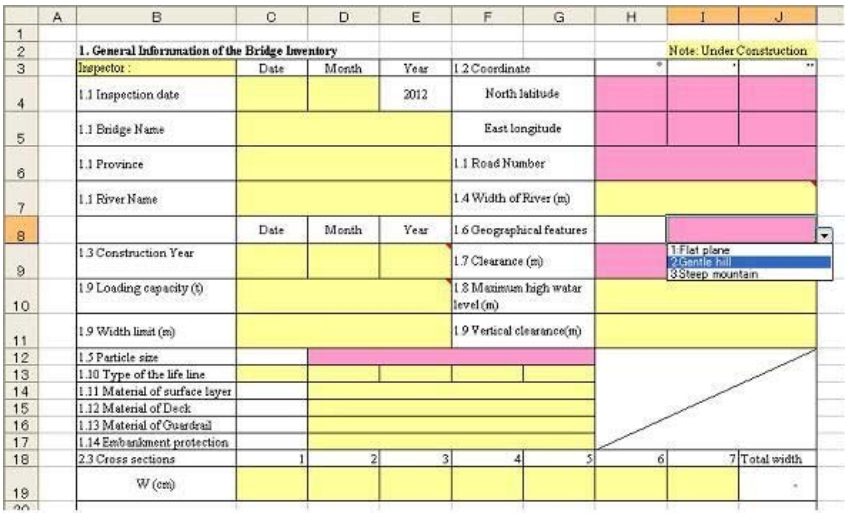
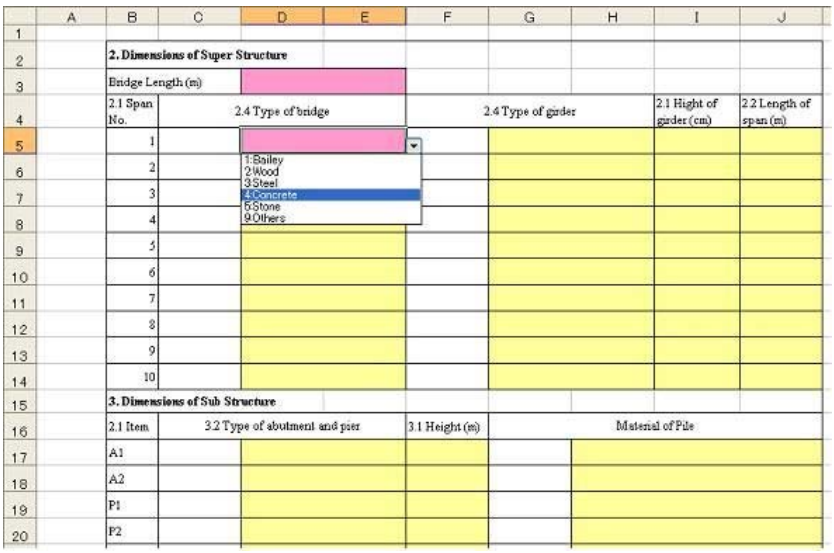
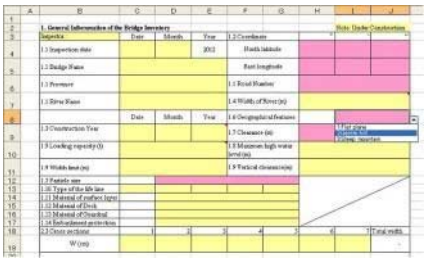



**Table 8-3 Bridge Inspection Sheet (2)**



Inspection Sheet



Information of Inspection Sheet is convert into Bridge

| | A | B | C | D | E | F | G | H | I | J | K | L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | インポート | Kmlファイル作成 | 諸元設定 | | | | | | | | | |
| 2 | 列数 | 14 | | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 3 | Sheet Name | | | | | Information | Information | Information | Information | Information | Information | Information |
| 4 | 抽出セル(行) | | | | | 4 | 4 | 4 | 5 | 5 | 5 | 6 |
| 5 | 抽出セル(列) | | | | | 8 | 9 | 10 | 8 | 9 | 10 | 8 |
| 6 | | | | | | North latitude | | | East longitude | | | |
| 7 | No. | Filename | Route Number | sig | No. | ° | ' | '' | ° | ' | '' | Road number |
| 8 | 1 | SIEB-R154-0001.xlsx | 154 | | 1 | 12 | 32 | 51.4 | 103 | 55 | 16.5 | 154 |
| 9 | 2 | SIEB-R154-0002.xlsx | 154 | | 2 | 12 | 35 | 4.5 | 103 | 57 | 22.2 | 154 |
| 10 | 3 | SIEB-R154-0003.xlsx | 154 | | 3 | 12 | 35 | 4.7 | 103 | 57 | 41.7 | 154 |
| 11 | 4 | SIEB-R154-0005.xlsx | 154 | | 4 | 12 | 36 | 48.0 | 103 | 59 | 29.0 | 154 |
| 12 | 5 | SIEB-R154-0006.xlsx | 154 | | 5 | 12 | 37 | 26.4 | 104 | 0 | 26.2 | 154 |
| 13 | 6 | SIEB-R154-0007.xlsx | 154 | | 6 | 12 | 37 | 6.8 | 104 | 0 | 59.1 | 154 |
| 14 | 7 | SIEB-R154B-0001.xlsx | 154 | B | 1 | 12 | 39 | 59.7 | 103 | 52 | 17.5 | 154B |
| 15 | 8 | SIEB-R154F-0001.xlsx | 154 | F | 1 | 12 | 40 | 41.1 | 103 | 38 | 34.0 | 154F |
| 16 | 9 | SIEB-R154F-0003.xlsx | 154 | F | 2 | 12 | 42 | 30.4 | 103 | 38 | 9.1 | 154F |
| 17 | 10 | SIEB-R154F-0004.xlsx | 154 | F | 3 | 12 | 42 | 44.6 | 103 | 38 | 4.7 | 154F |
| 18 | 11 | SIEB-R154F-0005.xlsx | 154 | F | 4 | 12 | 44 | 15.3 | 103 | 37 | 32.6 | 154F |
| 19 | 12 | SIEB-R155-0001.xlsx | 155 | | 1 | 12 | 30 | 54.6 | 103 | 55 | 16.8 | 155 |
| 20 | 13 | SIEB-R155-0002.xlsx | 155 | | 2 | 12 | 30 | 43.3 | 103 | 55 | 15.3 | 155 |
| 21 | 14 | SIEB-R155-0003.xlsx | 155 | | 3 | 12 | 30 | 21.4 | 103 | 55 | 12.4 | 155 |
| 22 | 15 | SIEB-R155-0004.xlsx | 155 | | 4 | 12 | 29 | 58.1 | 103 | 55 | 9.2 | 155 |
| 23 | 16 | SIEB-R155-0005.xlsx | 155 | | 5 | 12 | 29 | 34.5 | 103 | 55 | 6.1 | 155 |
| 24 | 17 | SIEB-R155-0006.xlsx | 155 | | 6 | 12 | 28 | 0.1 | 103 | 54 | 3.8 | 155 |
| 25 | 18 | SIEB-R155-0007.xlsx | 155 | | 7 | 12 | 27 | 49.5 | 103 | 53 | 47.2 | 155 |
| 26 | 19 | SIEB-R155-0008.xlsx | 155 | | 8 | 12 | 22 | 17.7 | 103 | 47 | 27.0 | 155 |
| 27 | 20 | SIEB-R155-0009.xlsx | 155 | | 9 | 12 | 20 | 56.3 | 103 | 46 | 24.2 | 155 |
| 28 | 21 | SIEB-R155-0010.xlsx | 155 | | 10 | 12 | 17 | 16.1 | 103 | 48 | 23.0 | 155 |

Click　　Multiple information are possible to confirm and referred on the bridge list

**1. General Information of the Brdige Inventory**

| Inspector : AING Thanith | Date | Month | Year | 1.2 Coordinate | ° | ' | '' |
|---|---|---|---|---|---|---|---|
| Inspection date | 28 | 4 | 2012 | North latitude | 13 | 28 | 15.1 |
| Bridge Name | Kouk Kdouch | | | East longitude | 103 | 04 | 25.2 |
| Province | Banteay Meanchey | | | Road Number | 156C | | |
| River Name | Unknown | | | Width of River (m) | 10 | | |
| | Date | Month | Year | Geographical features | 1 | Flat plane | |
| Construction Year | | | Unknown | Clearance (m) | 3.4 | | |
| Loading capacity (t) | None | | | Maximum high watar level (m) | -0.4 | | |
| Width limit (m) | None | | | Vertical clearance(m) | None | | |
| Particle size | 1 | Fine | | | | | |
| Type of the life line | | | | | | | |
| Material of surface layer | 2 | Concrete | | | | | |
| Material of Deck | 1 | Concrete | | | | | |
| Material of Guardrail | | | | | | | |
| Embankment protection | 1 | | | | | | |

| Cross sections | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Total width |
|---|---|---|---|---|---|---|---|---|
| W (cm) | 21 | - | 407 | - | - | - | 22 | 450 |

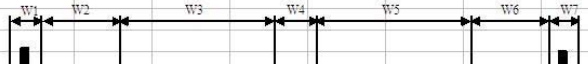
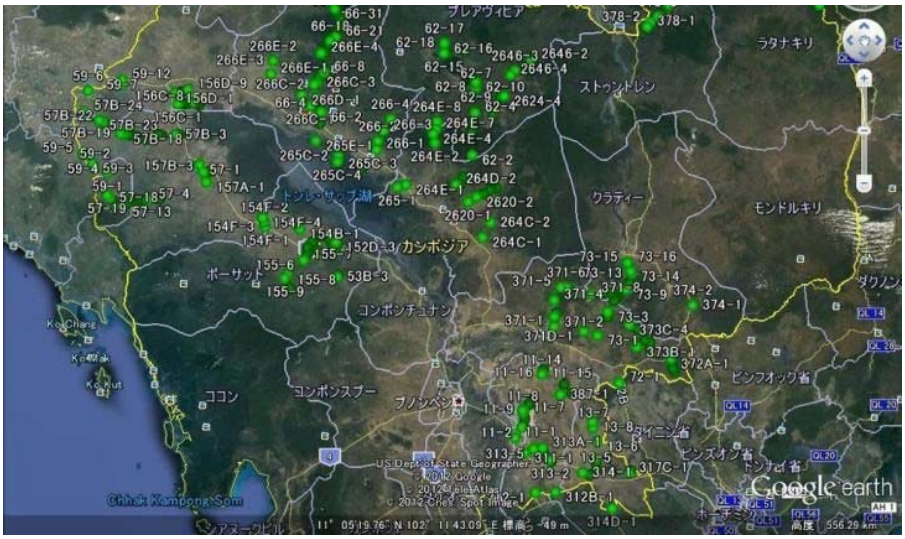



**Figure 8-3 Process of bridge information in the database convert in to bridge list**

Bridge locations on the list

| | A | B | C | D | E | F | G | H | I | J | K | L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | インポート | Kmlファイル作成 | 雛元設定 | | | | | | | | | |
| 2 | 列数 | 14 | | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 3 | Sheet Name | | | | | Information | Information | Information | Information | Information | Information | Information |
| 4 | 抽出セル(行) | | | | | 4 | 4 | 4 | 5 | 5 | 5 | 6 |
| 5 | 抽出セル(列) | | | | | 8 | 9 | 10 | 8 | 9 | 10 | 8 |
| 6 | No | Filename | Route | | No | North latitude | | | East longitude | | | Road number |
| 7 | | | Number | sig | | ° | ' | '' | ° | ' | '' | |
| 8 | 1 | SIEB-R154-0001.xlsx | 154 | | 1 | 12 | 32 | 51.4 | 103 | 55 | 16.5 | 154 |
| 9 | 2 | SIEB-R154-0002.xlsx | 154 | | 2 | 12 | 35 | 4.5 | 103 | 57 | 22.2 | 154 |
| 10 | 3 | SIEB-R154-0003.xlsx | 154 | | 3 | 12 | 35 | 4.7 | 103 | 57 | 41.7 | 154 |
| 11 | 4 | SIEB-R154-0005.xlsx | 154 | | 4 | 12 | 36 | 48.0 | 103 | 59 | 29.0 | 154 |
| 12 | 5 | SIEB-R154-0006.xlsx | 154 | | 5 | 12 | 37 | 26.4 | 104 | 0 | 26.2 | 154 |
| 13 | 6 | SIEB-R154-0007.xlsx | 154 | | 6 | 12 | 37 | 6.8 | 104 | 0 | 59.1 | 154 |
| 14 | 7 | SIEB-R154B-0001.xlsx | 154 | B | 1 | 12 | 39 | 59.7 | 103 | 52 | 17.5 | 154B |
| 15 | 8 | SIEB-R154F-0001.xlsx | 154 | F | 1 | 12 | 40 | 41.1 | 103 | 38 | 34.0 | 154F |
| 16 | 9 | SIEB-R154F-0003.xlsx | 154 | F | 2 | 12 | 42 | 30.4 | 103 | 38 | 9.1 | 154F |
| 17 | 10 | SIEB-R154F-0004.xlsx | 154 | F | 3 | 12 | 42 | 44.6 | 103 | 38 | 4.7 | 154F |
| 18 | 11 | SIEB-R154F-0005.xlsx | 154 | F | 4 | 12 | 44 | 15.3 | 103 | 37 | 32.6 | 154F |
| 19 | 12 | SIEB-R155-0001.xlsx | 155 | | 1 | 12 | 30 | 54.6 | 103 | 55 | 16.8 | 155 |
| 20 | 13 | SIEB-R155-0002.xlsx | 155 | | 2 | 12 | 30 | 43.3 | 103 | 55 | 15.3 | 155 |
| 21 | 14 | SIEB-R155-0003.xlsx | 155 | | 3 | 12 | 30 | 21.4 | 103 | 55 | 12.4 | 155 |
| 22 | 15 | SIEB-R155-0004.xlsx | 155 | | 4 | 12 | 29 | 58.1 | 103 | 55 | 9.2 | 155 |
| 23 | 16 | SIEB-R155-0005.xlsx | 155 | | 5 | 12 | 29 | 34.5 | 103 | 55 | 6.1 | 155 |
| 24 | 17 | SIEB-R155-0006.xlsx | 155 | | 6 | 12 | 28 | 0.1 | 103 | 54 | 3.8 | 155 |
| 25 | 18 | SIEB-R155-0007.xlsx | 155 | | 7 | 12 | 27 | 49.5 | 103 | 53 | 47.2 | 155 |
| 26 | 19 | SIEB-R155-0008.xlsx | 155 | | 8 | 12 | 22 | 17.7 | 103 | 47 | 27.0 | 155 |
| 27 | 20 | SIEB-R155-0009.xlsx | 155 | | 9 | 12 | 20 | 56.3 | 103 | 46 | 24.2 | 155 |
| 28 | 21 | SIEB-R155-0010.xlsx | 155 | | 10 | 12 | 17 | 16.1 | 103 | 48 | 23.0 | 155 |

Bridge location indicated on the Google Earth Map




Bridge location confirmed on the Map


**Figure 8-4 Coordinate of bridges converted into Google Earth Map**

## 8.4 Development of the Bridge Management System

### (1) Basic Policy of the System Development

Basic policy for development of bridge management system is shown as follows. Practical contents for the system shall be discussed through a future project.

1) Role of the Bridge Management System

BMS is not mere software but a total system which combines engineers, organizations, tools and manuals into management and implements the bridge maintenance continuously.

2) Unification of the data

Data relevant to bridge management including structural data, inspection data design drawings and as built drawings maintained by several division of the MPWT shall be unified into one system in principle. The unification of data management through network is not applicable in the existing circumstances in the MPWT. Therefore, design documents and drawings shall be managed by document data base and bridge structural data, inspection data and repair record shall be managed by the data base for the bridge maintenance.

3) Clarification of the flow of data management

Data for bridge maintenance including structural data, inspection data and repair record shall be maintained continuously. Responsibility of each division concerning the bridge maintenance and flow of the data shall be clarified.

4) Preparation of manuals relevant to bridge maintenance

Bridge inspection manual for proper evaluation of bridge conditions and bridge maintenance manual shall be prepared. Seminars for the manuals have to be held for exact understanding of bridge maintenance by inspectors.

5) Study the system component considering the environment in the MPWT

System component including stand-alone system, central and server system and web system shall be studied taking into consider the progress of the network environment, saturation level of the personal computer, schedule of the procurement of other systems and system users. Hardware and software necessary for the system operation shall be clear.

6) Method for identifying bridges

There are lot of bridges without their own names so they shall be distinguished and administered by the road number, coordination, and sequential no on the road. The system need to have a function to mark the location of the bridge on the map.

7) Function of the system

Basic functions necessary for the Bridge Management System are as follows

a) Support the input of bridge inspection information

b) Evaluation of the bridge deterioration and prioritization for repair based on the inspection report

c) Planning for bridge repair and estimate the repair cost

d) Output of bridge information

Various departments in the government and business world are involved in the operation of BMS because the bridges are important social infrastructure and their maintenance needs support from various areas. Organization and responsibility for the bridge maintenance for each division within the MPWT and the DPWT need to be discussed for proper operation of BMS. Image and functions of the BMS are shown in Figure 8-5.

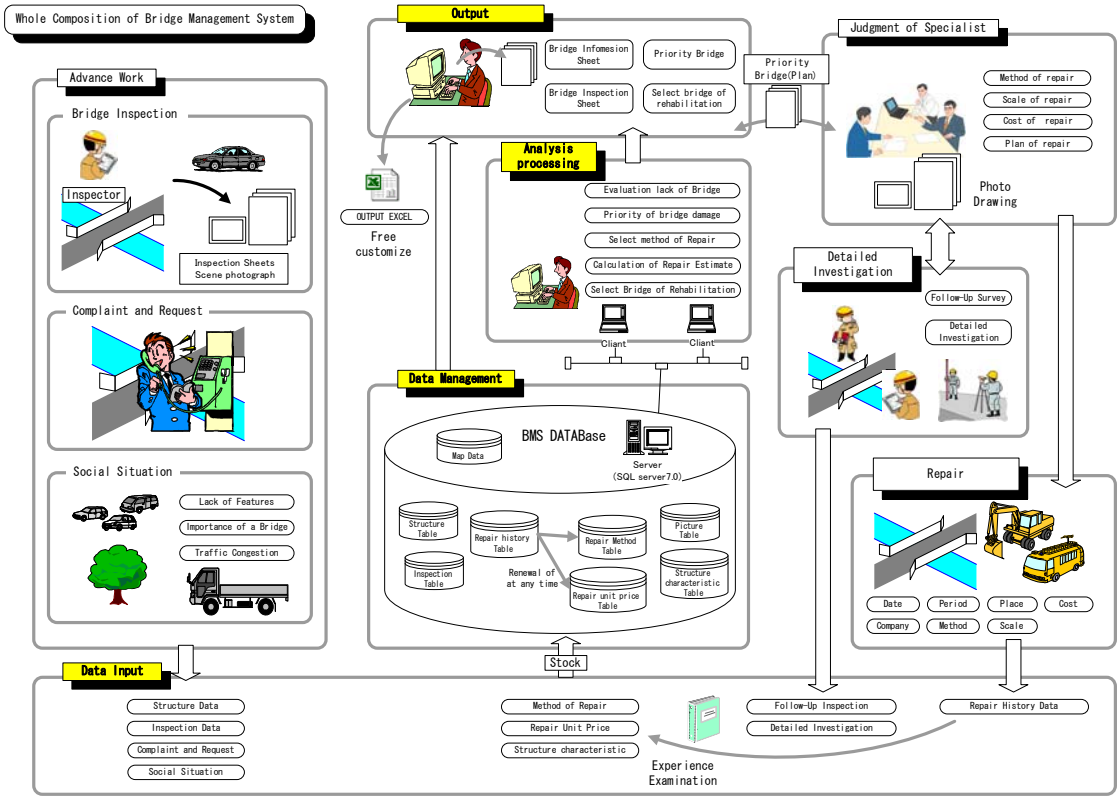


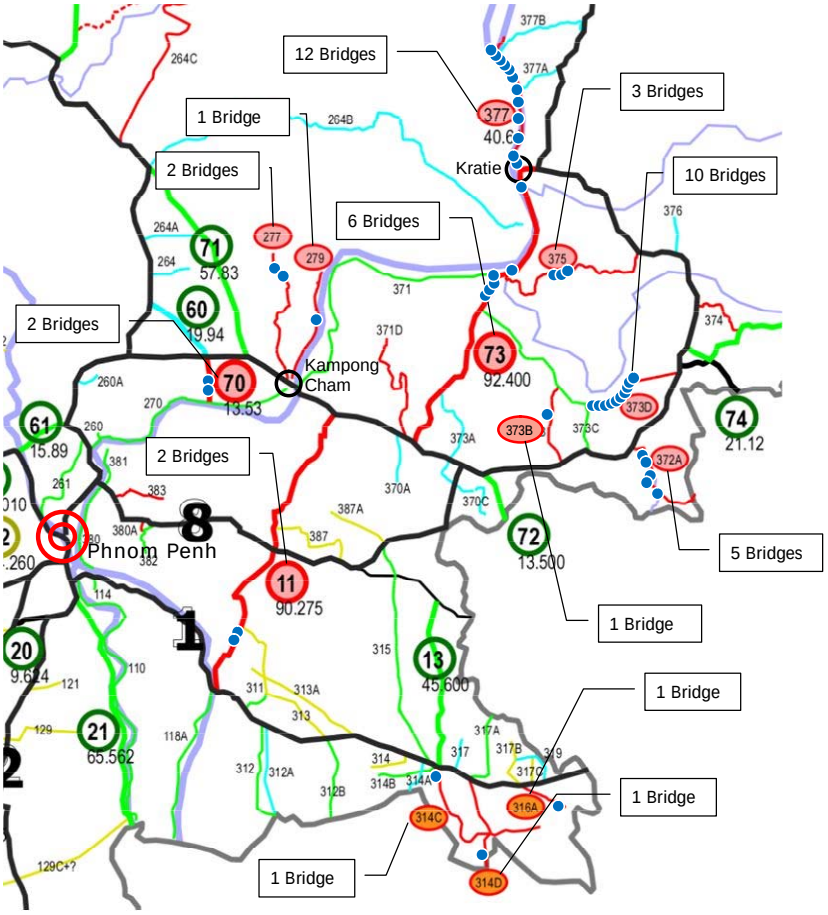

**Figure 8-5 Image of the Bridge Management System**

# 9. ENVIRONMENTAL AND SOCIAL CONSIDERATIONS

## 9.1 Project Components

The Study Team prioritized 47 bridges on 13 roads in the Section 2.3. Lengths of the bridges are from minimum 10 metres up to maximum 150 metres. Only four bridges have over 100 metres in length. For these bridges, they have no large-scale, and the expected project activity is replacement of the existing bridges, therefore, basically it does not significantly change the existing environmental and social conditions. As the process of replacement consists of construction of diversion including temporary bridge, building of construction road, demolishment and clearance of the existing bridge, and construction of new bridge, most likely slight impacts to the environment are expected in the construction period.

13 roads and 47 bridge sites are located in four provinces, i.e. Kampong Cham, Kratie, Prey Veng, and Svay Rieng in the east of the country as shown in Figure 9-1. Physical features around them are not mountainous but comprise flat plains or gentle hills.




Source: Study Team

**Figure 9-1 Locations of the Prioritized Roads and Bridges**

## 9.2 Outlines of the Project Sites

### (1) Topography

Topographical condition is generally flat with maximum elevation up to 7 metres for the bridge number 2 and on NR11 in Prey Veng province. In Kampong Cham province, the topographical conditions around the bridges are generally flat with maximum elevation up to 25 m, except for the bridges numbers 1,2,3,4 and 5 on PR372A and bridge number on PR373B which are gentle hill with maximum elevation up to 95 metres. In Kratie province, the topographical conditions are also generally flat with maximum elevation from 10 to 25 metres. In Svay Rieng, the topographical conditions are generally flat with maximum elevation from 3 to 5 metres.

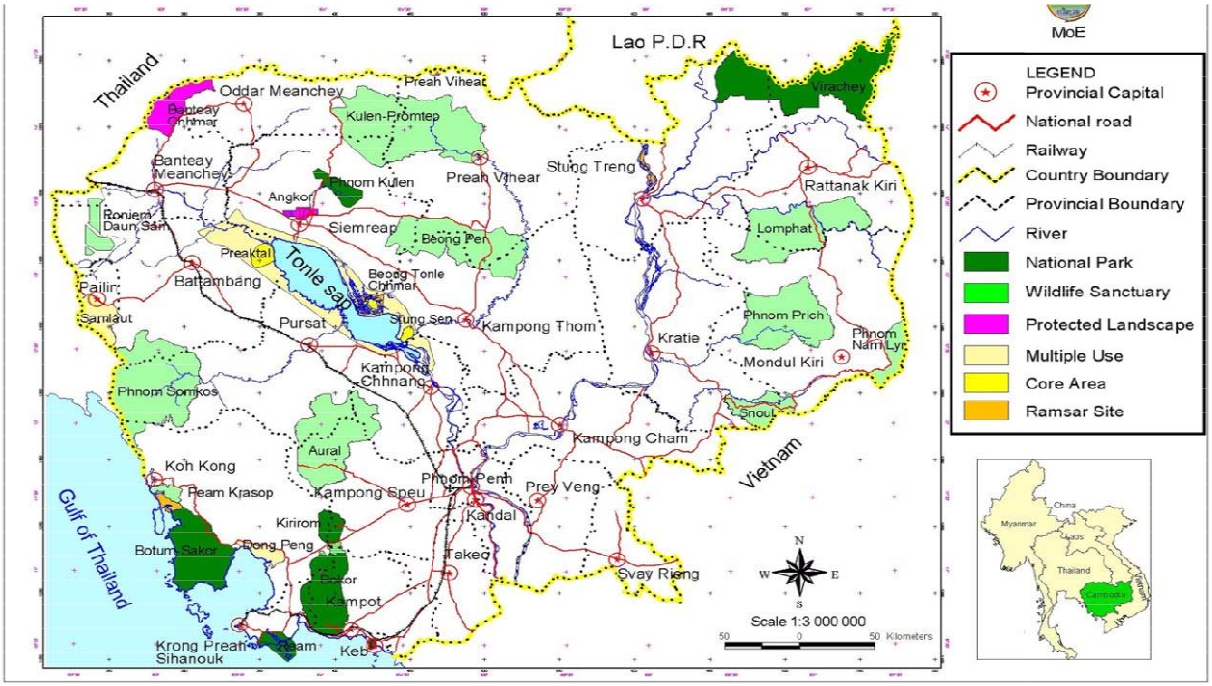
The project area has a growing agricultural sector; producing maize, cassava, sesame, sweet potato, sugarcane, soya beans, mung beans, black pepper, sugar cane and cashew nuts. Besides, the province is well known as a major rubber producer of the country. The Svay Rieng province is well known as a major rice producer of the country.

### (2) Climate

The Study area has a predominantly monsoon climate and has been described as tropical wet and dry due to the distinct seasonal variation. Approximately 70-80% of annual rainfall occurs from mid-May to late September or early October. The northeast monsoon brings drier and cooler air from early November to March. The hotter conditions prevail in April and early May as dry season.

### (3) Protected Areas

Protected conservation areas cover approximately 5.4 million hectares in the national territory. They consist of seven national parks, nine wildlife sanctuaries, three protected landscape areas, and three protected areas. The national parks are located in the coastal, mountain, plateau and lake regions covering 742,300 hectares and 4,138,000 hectares for wildlife sanctuaries. The protected landscape areas cover 97,000 hectares including archaeological and cultural sites, and protected areas cover 403,900 hectares. However, there are no protected areas around the locations of the bridges.




Source: MOE

**Figure 9-2 Locations of Protected Areas**

### 9.2.2 Route-side Socio-economic Conditions

In Kampong Cham, Kratie, Prey Veng, and Svay Rieng provinces where 13 roads and 47 bridge sites are located, the socio-economic conditions of villages on the route-sides are: i) the industries are dominated by agriculture; ii) a few areas are urbanized from the conditions of household's living infrastructure. The areas seem to be typical rural areas in Cambodia.

Power supply is limited in households of villages and they mainly use batteries. Firewood is widely used for cooking fuel. Most households have no toilet facilities and no piped water supply. Boreholes, open wells or surface water are main sources of water supply for them.

Regarding social services, a health center is not placed at village level but at commune level (the next administration level from village). Basically, a secondary school is also placed at commune level and some communes have even high schools. Any communes have at least one primary school or more than one primary school.

## 9.3 Scoping and TOR of Environmental and Social Study

### 9.3.1 The Purpose of Environmental and Social Study

The work items of Environmental and Social Study for the Package A are as follows.

1) Confirmation of the environmental and social considerations system in Cambodia
2) Collection of the baseline information
3) Site survey and scoping on the prioritized roads and bridges
4) Estimate and assess the environmental and social impact from the Project.

5) Propose the mitigation measures

6) Disclose the information to the organization concerned.

Since the bridges on roads connecting the Southern Economic Corridor are supposed to be important, scoping of these roads and bridges will be carried out in the early stage of the study. Especially for the items 2), 3), 4) and 5), an environmental and social survey will be implemented with a sub-contract of a local consultant because the number of the bridges to be replaced can be many and those locations can disperse widely.

The Project is categorized as "Category B" because it does not exert serious impacts on the environment and social situations and the study is required at Initial Environmental Evaluation (IEE) level in accordance with JICA guideline of April 2004.

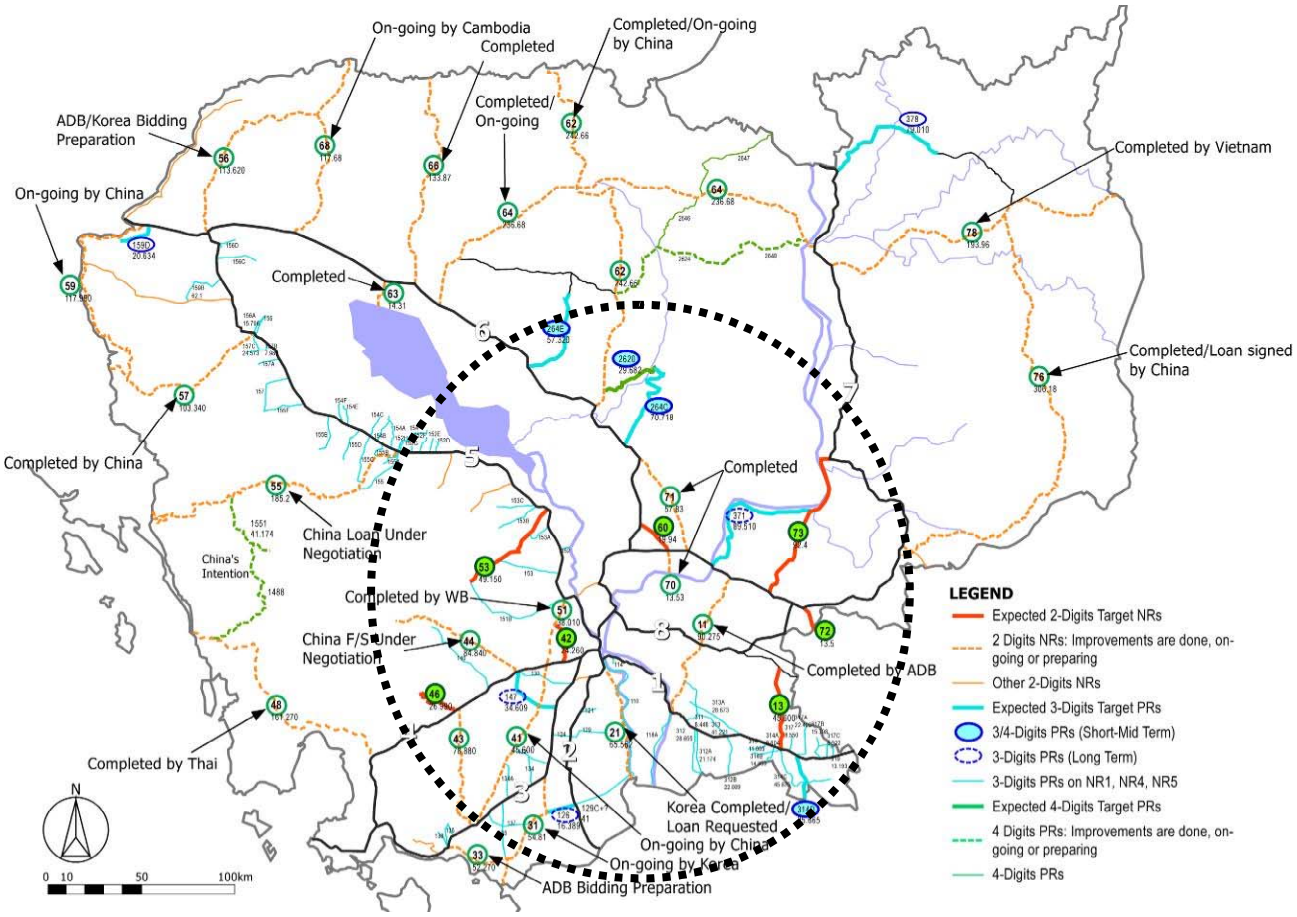
Besides, the Project is not for Feasibility Study and the Environmental and Social Study does not directly support implementation of IEIA or EIA in Cambodian environmental impact assessment procedure. Therefore, the survey with a sub-contract of a local consultant will be conducted for preparing information and study including items 2)-5) mentioned above at IEE level in order to promptly conduct IEIA or EIA toward implementation of the bridge replacement project.

### 9.3.2 Preliminary Scoping

#### (1) Preliminary Selection of the Target Roads for the Preliminary Scoping

The bridge inventory survey and traffic count survey were conducted for the prioritization; however, those surveys needed time to obtain their outcomes. Therefore, the target roads were selected for the preliminary scoping based on the following points of view.

- Exclude 2-digit roads on which surface and bridges have already been improved, the improvement is on-going or other donors have intentions based on 1) the list of Project Profile & Progress provided by the MPWT, 2) opinions in the first counterpart meeting, and 3) site reconnaissance by the Study Team.
- 2-digit roads which were recommended for the short or medium-term projects in the "Follow-up Study on the Road Network Development Master Plan 2009".




Source: Study Team

**Figure 9-3 Preliminary Target Roads for the Preliminary Scoping**

### (2) Preliminary Scoping

The Study Team conducted site reconnaissance and did a preliminary scoping based on the following policies to plan further Environmental and Social Study.

- Target roads: 2-digit roads expected for the priority of the roads shown in Figure 9-3.
- Surveyed roads: NR60, NR42, NR13, NR72, NR73, NR53, NR46 and PR314D (This 3-road was also surveyed as connecting NR1 and a border gate of Vietnam.)
- Expected types of bridges to be replaced: Bailey bridge, wooden bridge, steel bridge (actually depending on degree of deterioration and year of construction)
- Expected bridges to be replaced were surveyed and results were collectively evaluated as the preliminary scoping.
- Major characteristics of environmental conditions around the surveyed bridges depended on length of the bridges, the locations on a river, on a flood plain (on a way of water transmission in flood, there is no water flow in dry season), or on a river in mountainous area.
- The expected project activity is replacement of the existing bridges, therefore, basically it does not significantly change the existing environmental and social conditions.

- As the process of replacement is construction of diversion, construction of temporary bridge, demolishment and clearance of the existing bridge, most likely negative impacts are expected in the construction phase.
- However, as the Package A aims at prioritization of the bridges to be replaced and the Study does not include construction method and implementation schedule, consequently the locations of temporary bridges and diversions (closer places are required) are still unclear.
- Therefore, the area within ROW (25m each side from the road centre in 2-digit roads) is assumed as the construction area.
- In the process of replacing the bridges, there are some structures within the ROW and temporary relocation or involuntary resettlement will occur to secure the space of diversions and replacement works (e.g. NR73).

### (3) Draft TOR of Environmental and Social Study

A draft TOR of further Environmental and Social Study is summarized in Table 9-1 based on the results of preliminary scoping.

**Table 9-1 Draft TOR of Environmental and Social Study**

| | No. | Likely Impacts | Phase/ Rating | Study Item | Study Method |
|---|---|---|---|---|---|
| Social Environment: | 1 | Involuntary Resettlement | Pre-constr. B- | • Scale of potential area, buildings or households for temporary relocation or involuntary resettlement<br>• Policy of resettlement | • Collection of relevant legislations<br>• Site reconnaissance for the numbers of buildings, locations, households, types<br>• Site reconnaissance for land use |
| | 2 | The poor people | Pre-constr. C- | • Existence of poor people nearby the bridges | • Site reconnaissance<br>• Hearing to the residents nearby the bridges and local government |
| | 3 | The indigenous and ethnic people | Pre-constr. C- | • Existence of ethnic minority nearby the bridges | • Site reconnaissance<br>• Hearing to the residents nearby the bridges and local government |
| | 4 | Local economy such as employment and livelihood, etc. | Constr. B+/- Operation B+ | • Socio-economic situations of District, Commune, or Village, which includes the bridges | • Study on existing information (literature survey)<br>• Site reconnaissance<br>• Hearing for District, Commune, or Village Offices<br>• Hearing for nearby residents |
| | 5 | Land use and utilization of local resources | Constr. B- | • Land use situations nearby the bridges | • Site reconnaissance for land use |
| | 6 | Water Usage or Water Rights and Rights of Common | Constr. B- | • Situations of water use and fishery in the rivers nearby the bridges | • Site reconnaissance<br>• Hearing for District, Commune, or Village Offices<br>• Hearing for nearby residents |
| | 7 | Existing social infrastructures and services | Constr. B- Operation C+ | • Infrastructure on the bridges and approach roads<br>• Public facilities around the bridges | • Site reconnaissance<br>• Hearing for District, Commune, or Village Offices<br>• Hearing for nearby residents<br>• Hearing for public facilities (clinics, schools) |
| | 11 | Cultural heritage | Constr. B- | • Temples, monuments nearby the bridges | • Site reconnaissance<br>• Hearing for nearby residents |

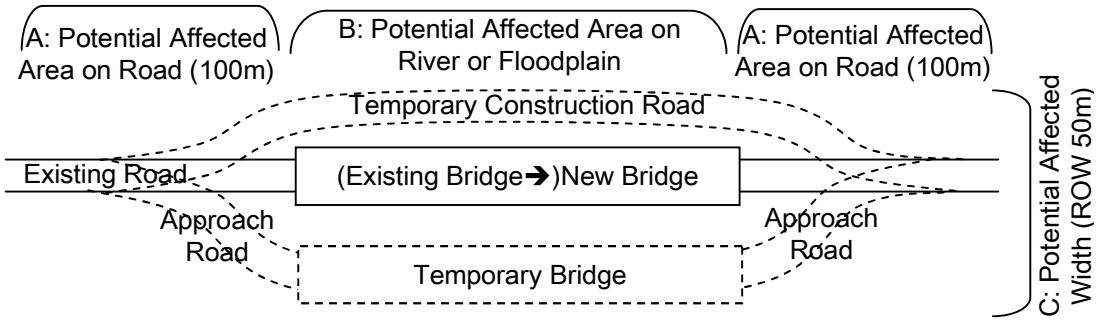
| | No. | Likely Impacts | Phase/ Rating | Study Item | Study Method |
|---|---|---|---|---|---|
| | 15 | Hazards (Risk), Infectious diseases such as HIV/AIDS | Constr. B- | • Situations of diseases including HIV/AIDS around the bridges | • Study on existing information (literature survey)<br>• Hearing for relevant organizations<br>• Hearing for District, Commune, or Village Offices |
| | 16 | Working conditions | Constr. B- | • Policy and measures for working security | • Study on labour standards<br>• Study case examples of contracts regarding working conditions |
| Natural Environment | 17 | Protected Areas | Constr. C- | • Existence of protected areas nearby the bridges | • Study on the existing information (literature survey)<br>• Hearing and data collection for/from relevant organizations (MOE, MAFF)<br>• Site reconnaissance |
| | 18 | Flora, Fauna and Biodiversity | Constr. B- | • Types of flora and fauna around the bridges<br>• Existence of indigenous and endangered species | • Study on the existing information (literature survey)<br>• Hearing and data collection for/from relevant organizations (MOE, MAFF)<br>• Site reconnaissance<br>• Hearing for nearby residents |
| | 19 | Hydrological Situation | Constr. C- | • Situations of seasonal water flow (directions, water levels) | • Site reconnaissance<br>• Hearing for nearby residents |
| | 21 | Soil Erosion | Constr. B- | • Methods of slope surface by cut and fill | • Study description of works, construction methods, period, types of machinery |
| Pollution | 24 | Air Pollution | Constr. B- | • Preventive measures for exhaust gases/dust from construction vehicle and equipment | • Study description of works, construction methods, period, types of machinery |
| | 25 | Water Pollution | Constr. B- | • Methods of slope surface by cut and fill | • Study description of works, construction methods, period, types of machinery |
| | 26 | Waste | Constr. B- | • Disposal solutions for construction waste including demolished bailey bridges | • Hearing for relevant organization (MPWT) |
| | 27 | Soil Contamination | Constr. B- | • Preventive measures for leaks of fuel/oil from construction vehicle and equipment | • Study description of works, construction methods, period, types of machinery |
| | 28 | Noise and Vibration | Constr. B-<br>Operation C+ | • Preventive measures for noise/ vibration from construction vehicle and equipment<br>• Noise from the existing bailey bridges | • Study description of works, construction methods, period, types of machinery<br>• Hearing for nearby residents |
| | 30 | Offensive Odor | Constr. C- | • Preventive measures for odor from construction vehicle and equipment | • Study description of works, construction methods, period, types of machinery |
| Others | 32 | Accidents | Constr. B-<br>Operation B- | • Accidents during construction works on labours and residents<br>• Traffic accidents after the replacement of bridges around them | • Hearing for contractors<br>• Hearing for residents nearby some brides replaced before |

Source: Study Team

## 9.4 Results of the Study

Results of the detailed Environmental and Social Study for each prioritized bridge are reported in the Environmental and Social Profiles attached in Volume I. As the Package A aims at prioritization of the bridges to be replaced in the Study and the Study does not include design, construction method and implementation schedule, consequently the locations of temporary bridges and diversions were not shown at the sites.

Therefore, the study area was specified as shown in Figure 9-4. An area within ROW which is designated as 25 metres each side from the road centre in 2-digit roads was assumed for a Potential Affected Area (hereinafter referred to as PAA) from the construction works. The site survey of Environmental and Social Study was conducted in the PAAs mainly with observation and interviews for the residents. All 47 bridges are located in flat plain or gentle hill areas and more than half of them have annual river water flows below the bridges.




Source: Study Team

**Figure 9-4 Potential Affected Area around the Prioritized Bridges**

**Table 9-2 Results of Environmental and Social Study**

| No. | Likely Impacts | Results |
|---|---|---|
| 1 | Involuntary Resettlement | Major buildings and population in the PAAs were identified through the site survey. Population and number of households in the PAAs were estimated with the results of questionnaire survey for the residents in the PAAs. Total 120 households were interviewed in the survey. The PAAs which populations over 100 are bridge numbers 70-2, 73-4, 279-7, and 377-1/2/5/7. Those are located on the roads along the Mekong except 70-2. Especially, PR377 located north of Kratie Town is densely populated. |
| 2 | The poor people | Wooden walls with tiled roofs and zinc roofs dominate the building structures in the PAAs. Most interviewed families owned the buildings and land, and some families rented the buildings and land. The families mainly use city power and batteries as the source of light. However, few families use pipe water for drinking water. Firewood is the source of cooking fuel for them. About 70% households have no toilet in premises. These living conditions appear like a typical rural area in Cambodia.<br>However, based on average monthly household incomes heard in the interviews, households under WB poverty line (daily US$ 1.25 per capita) were found in each PAA where some residents were identified. However, the answers were still unclear since not all household heads were interviewed due to their unavailability and limited survey time. Project Affected Persons (PAPs) will be identified in further study, Detailed Measurement Survey (DMS) will be conducted, and monthly incomes will be also surveyed. |

| | | |
|---|---|---|
| 3 | The indigenous and ethnic people | Based on the interviews to the households, no indigenous and ethnic people were identified around the bridge. Ethnicities of all interviewees who live around the bridges were Khmer and they had Cambodian nationality. |
| 4 | Local economy such as employment and livelihood, etc. | (1) Major Income Sources of Local People<br>Most households have major income sources from self-employment (shops) and farming (rice, potato, cassava, corn, rubber). Other income sources are permanent employed government officers, fishing and motorcycle taxi driver although these are few.<br>(2) Expected Construction Workers<br>In case of bridge replacement works for 30 metre length, the following construction workers are assumed for each type of work.<br>• Superstructure work: bridge chief, special worker, reinforcement workers (3), formwork workers (3), general workers (5-10), truck crane driver<br>• Base structure work: general chief, reinforcement workers (3), formwork workers (3), steeplejack (3), general workers (5-10), truck crane driver<br>• Foundation work: general chief, steeplejack (3), special worker, general workers (5-10), reinforcement workers (3), concrete workers (3), diesel pile hammer driver, backhoe driver<br>• Road work: general chief, special worker, general workers (5-10), Asphalt finisher driver, road roller driver, tire roller driver |
| 5 | Land use and utilization of local resources | Major land uses in the PAAs were dominated by residential land, farmland, shrub land and grassland. |
| 6 | Water Usage or Water Rights and Rights of Common | Annual river water and seasonal surface water nearby the bridges are used by local people especially for washing, cleaning of equipment/farming gears/motor cycles, bathing or fishing. |
| 7 | Existing social infrastructures and services | Telephone cables and electric cables are installed with poles around most of the bridges. Water supply pipes are also laid on several bridges and even optical cables are laid on a few bridges. A few schools, police and guard posts or rest halls were observed in the PAAs of the bridge numbers: 279-7, 372A-3, 314C-1, 314D-1, 316A-1. |
| 11 | Cultural heritage | Specific cultural heritages were not identified nearby the bridges. However, two pagodas were observed in two PAAs. One was near bridge number 73-8 and the other was near bridge number 372A-3. |
| 15 | Hazards (Risk), Infectious diseases such as HIV/AIDS | Most local diseases expressed by interviewees of local people living around the bridges are common cold, while Dengue fever, diarrhea and malaria are rate. Information on HIV/AIDS was not available from local health centers. |
| 16 | Working conditions | In Cambodia, Articles 229 and 230 of the Labour Law stipulate on the health and safety of workers as follows. The construction workers for the replacement works of the bridges are safeguarded by the law. Besides, contract of the bridge replacement works requires contractors a safety plan and an environmental management plan. |
| 17 | Protected Areas | Protected areas are not located around the bridges. |
| 18 | Flora, Fauna and Biodiversity | (1) Flora<br>Local surveyors visually checked flora around the bridges. Those typical flora are fruit trees (papaya, mango, banana, tamarind, jack fruit, guava), palm tree, coconut tree, kapok tree, makak tree, areca palm tree, rain tree, jujube tree, bamboo, eucalyptus and so on. They are common flora in Cambodia. However, the survey results included an EN (endangered) species name as follows. There were five rosewood trees in the residential land and those owners planted the trees about five years ago.<br>(2) Fauna<br>On the other hand, faunas was surveyed by interviewing local people while showing species lists with small pictures attached, and surveyors asked them whether they have seen these species around bridges. Therefore, many people indicated birds, mammals, reptiles, amphibians and fishes on their memories without limitation of time period and frequency. Most species answered were common species in Cambodia although the results included a few EN (endangered) species names. |
| 19 | Hydrological Situation | The bridges are installed not only over rivers but also at flood plains to transmit flood water from the Mekong, with gentle velocity. |

| | | |
|---|---|---|
| 21 | Soil Erosion | (1) The Existing Conditions<br>The most common soil type around the bridges is laterite. Local people recognized little erosion although fair erosion (small concavities) was observed in the site survey.<br>(2) Assumed Bridge Replacement Works<br>The bridge replacement works can cause soil erosion from slope surface by cut and fill at least temporarily in construction period. Typical works are described as follows.<br>1. Bridge replacement Conditions<br>1) Superstructure type: RCDG (reinforcement concrete deck girder)<br>2) Pier type: wall type pier, concrete driven pile<br>3) Bridge abutment type: reversed T-type abutment, concrete driven pile<br>4) Main girder construction method: by truck crane<br>5) Diversion type to cross river: temporary bridge, H-steel sheet pile<br>6) River diversion method: temporary diversion canal<br>2. Work schedule (about 16 months for 30m length)<br>1) Site office installation work (1 month)<br>2) Preparation work: diversion construction, temporary bridge construction, removal work (2 months)<br>3) Foundation work (1.5 months)<br>4) Base structure work (5 months)<br>5) Superstructure work and Road work: main girder work, bridge surface work (5 months)<br>6) Cleaning work (1 month) |
| 24 | Air Pollution | In the bridge replacement work period, exhaust gases and dust generated by the construction vehicles and machinery can be the sources of air pollution. However the construction period is short and type of construction equipment is small for the bridge replacement so that the influence to the environment at construction site will minimum. |
| 25 | Water Pollution | The existing sources of water pollution around the bridges were not heard from local interviewees. The soil erosion from the slope surface by cut and fill can degrade river water quality at least temporarily in construction period. |
| 26 | Waste | Local municipalities of rural areas in Cambodia generally do not have solid waste disposal systems. Therefore, contractors have to treat solid waste by themselves. Typical treatment method is to bury the solid waste in coordination with surrounding communities. Waste water is treated with septic tank as usual. |
| 27 | Soil Contamination | In the bridge replacement work period, unintentional considerable spilled fuel and oil from the construction vehicles and machinery can be the sources of soil contamination. |
| 28 | Noise and Vibration | The local people who live nearby the bridges recognized some or much noise and vibration especially from the bailey bridges while vehicle passing by. The bridges that noise and vibration were identified were bridge number 70-1/2, 73-4/8/16, 372A-1/2/3/4/5, 377-2/5, 314D-1.Major source of noise are steel deck of Bailey bridge and they will be improved after bridge replacement with permanent bridges. |
| 30 | Offensive Odor | The local residents did not recognize offensive odor nearby the bridges. The sources of offensive odor were not identified in the survey. In the bridge replacement work period, exhaust gases and dust generated by the construction vehicles and machinery, domestic water and wastes from site offices can be the sources of offensive odor. Types of the machinery for the bridge replacement work are assumed |
| 32 | Accidents | Typical possible accidents involving construction workers during the removal and construction works of bridges are falls, accidents by the construction vehicles and machinery. Residents around the construction sites can be involved in traffic accidents. The Labor Law requires the worker's health and safety, and contract of the bridge replacement works requires contractors to compile a safety plan and environmental management plan. The safety plan consists of safety manual and safety working practices, which include safety meeting/reporting, personal protective equipment, access control, obligations and cares of the works.<br>Other accident cases and, traffic accidents after the construction have been increased around the new bridges according to the interviews to local people who live nearby replaced bridges. They recognized traffic accidents increased after bridge replacements. |

Source: environmental and Social Survey 2012, JICA Study Team

## 9.5 Evaluation of Anticipated Environmental and Social Impacts

The results of evaluation show that the most important adverse impact is "Involuntary Resettlement". According to the building situations in the respective PAAs and the estimated population/numbers of households based on the environmental and social survey, the most concerned sites are 7 bridges, Bridge No. 73-4, 70-2, 279-7 and 377-1/2/5/7. Especially along PR377 northbound from Kratie Town, it is more densely built in the PAAs. In these PAAs where residential buildings are identified, a part of them can be affected in land acquisition and resettlement depending on the locations of a temporary bridge, a construction road or a material yard although they are still not clear.

The other adverse impacts due to the bridge replacement works are expected during the construction period. Natural environment of rivers with annual rover flows can be affected by the bridge replacement activities (demolition and construction works). In all PAAs, several pollutions can be expected due to the bridge replacement activities especially for the operations of construction vehicles. However, the scales of the bridge replacement activities are not large-scale at a maximum only 150m, consequently, those construction periods are rather short and extent of the impacts are limited around the bridges. Therefore, the bridge replacement works do not seriously affect the environment and social conditions around the bridges and the communities.

## 9.6 Mitigation Measures

In the pre-construction phase, land acquisition and resettlement are major adverse impacts from the Project. These will be basically mitigated in accordance with the Resettlement Action Plan (RAP) which will be prepared by MPWT with the assistance of consultants and the line agency, RD (MEF), in the feasibility study stage preferably or the designing stage at latest. On the other hand, adverse impacts on the natural environment and pollution are expected in the construction phase. The mitigation measures for them are incorporated into the Environmental Management Plan and Safety Plan as parts of the contract documents prepared with the engineering components of the Project.

## 9.7 Monitoring Plan

In the PAAs of the bridges set-up for the Study, houses/commercial buildings are identified in the PAAs of 31 bridges and some of them can be affected by the bridge replacement works. Therefore, preparation of RAP and the land acquisition/resettlement activities are the most important monitoring items. Another important monitoring item is annual river water quality especially for the bridges located along the routes nearby the Mekong. Table 9-3 summarizes the proposed monitoring plan. However, the MOE may give

some requests to be monitored on the IEIA report prepared and submitted for the Project implementation in the next step.

1) Major possible adverse impacts: land acquisition and resettlement, pollutions during the bride replacement works
2) Monitoring items considered by other bridge construction projects
3) Compliance with the Cambodian environmental standards

**Table 9-3 Proposed Monitoring Plan**

| Environmental Item | Monitoring Item | Location | Frequency | Responsible Organization |
|---|---|---|---|---|
| Pre-construction Phase | | | | |
| Involuntary Resettlement | Preparation of RAP | Producers of RAP | During RAP preparation | MPWT/IRC/ Development Partners |
| | Entitlements of PAPs under the approved entitlement policies | | | |
| | Assessment of compensation under the agreed procedures | | | |
| | Public information, public consultation and grievance procedures as stated in the RAP | Project sites | During resettlement activities in the processes | |
| | Payment of compensation as stated in the RAP | | | |
| | Payment of compensation in a timely manner | | | |
| | Functionality of Grievance Redress Mechanism | | | |
| Construction Phase | | | | |
| Air Pollution | CO, NO2, SO2, O3, Lead, Total Suspended particulate | Construction site | At start of construction/ Every month | Supervising consultant/ Contractor |
| Water Pollution | pH, BOD5, Suspended Solid, Dissolved Oxygen, Oil content, Total Nitrogen, Total Phosphorus, Coliform | Upstream and Downstream of bridge | At start of construction/ Every month | |
| Noise | Noise level (dBa) | Nearby residential houses | At start of construction/ Every month | |

Source: Study Team

## 9.8 Land Acquisition and Resettlement

### 9.8.1 Necessity of Land Acquisition and Resettlement

As previously explained, as Package A aims at prioritization of the bridges to be replaced in the Study and the Study does not include design, construction method and implementation schedule, consequently the locations of temporary bridges and diversions are still unclear at the sites. According to the results of Study including Bridge Inspection Survey and Environmental and Social Study, structures and residents are identified in the PAAs and some of them can be affected by the bridge replacement works depending on the locations of diversions, temporary bridges and material yards.

### 9.8.2 Legal Framework

#### (1) Legislation

Cambodian resettlement policy has been improved by implementation of international donor projects with JICA, ADB or WB according to requirements of their safeguard policies and compliance. The ADB has been supporting to prepare a sub-decree on the national resettlement policy, however, it has not been established yet. The Constitution and Land Law are still applied for resettlement as the basic laws.

#### (2) Procedure of Land Acquisition and Resettlement Works

Based on the public work experiences in Cambodia, Table 9-4 summarizes the land acquisition and resettlement work steps especially for international corporation projects although the procedures have not been legalized yet.

**Table 9-4 Land Acquisition and Resettlement Work Steps**

<table>
<tr><th colspan="2">Resettlement Steps</th><th colspan="2">Project Steps</th></tr>
<tr><td>A. Pre-Resettlement Implementation Stage</td><td rowspan="6">- Census (Number of Affected Persons, Socio-economic Survey)<br>- Public Information Meeting<br>- Resettlement Action Plan</td><td rowspan="2">Feasibility Study (F/S)</td><td rowspan="6">Pre-Implementation</td></tr>
<tr><td>(1) Resettlement Planning</td></tr>
<tr><td>(2) Institutional Arrangements</td></tr>
<tr><td>B. Resettlement Implementation Stage</td></tr>
<tr><td>(3) Detailed Measurement Survey (DMS)</td></tr>
<tr><td>(4) Replacement Cost Study (RCS)</td><td>Approval</td></tr>
<tr><td>(5) RAP updating and Budgeting</td><td rowspan="6">- Detailed Measurement Survey (Property Evaluation)<br>- Replacement Cost Survey<br>- Compensations Calculation<br>- RAP Updating<br>- Negotiation and Contract<br>- Relocation Site Preparation<br>- Payment and Relocation</td><td rowspan="5">Design / Procurement</td><td rowspan="6">Resettlement Implementation</td></tr>
<tr><td>(6) Relocation Site Preparation</td></tr>
<tr><td>(7) Negotiation and Contract</td></tr>
<tr><td>(8) Budget Disbursement and Payment</td></tr>
<tr><td>(9) Relocation</td></tr>
<tr><td>C. Cross-Cutting Issues</td></tr>
<tr><td>(10) Public Consultation Meeting (PCM)</td><td rowspan="3">- Monitoring<br>- Grievance Redress Mechanism<br>- Income Restoration Program</td><td rowspan="3">Construction</td></tr>
<tr><td>(11) Grievance Redress Mechanism (GRM)</td></tr>
<tr><td>(12) Monitoring and Evaluation</td></tr>
</table>

Source: MEF, MPWT, Study Team

# 10. IMPLEMENTATION PROGRAM

## 10.1 Target Bridges for the Replacement Plan

Replacement plans for target bridges including temporary bridge, bridge overflow by flood water and one lane bridge are examined in this chapter. The target bridges identified through the survey are classified as follows:

**Table 10-1 Summary of the Target Bridges**

| Classification of bridge | Type of bridge | | Number of bridge |
|---|---|---|---|
| Temporary bridge | A | Wooden bridge | 40 |
| | B | Bailey bridge | 54 |
| | C | Temporary steel bridge | 16 |
| | D | Temporary concrete bridge | 4 |
| | E | Bridge of grade3 | 2 |
| | Sub total | | 116 |
| Bridge over flow by a flood | F | Bridge deck overflow by the flood | 17 |
| | G | High water level reach to the bridge girder | 8 |
| One lane Bridge | H | Concrete one lane bridge | 78 |
| Total | | | 219 |

## 10.2 Concept for the Implementation Program

In order to carry out replacement of the target bridges within the constraints of limited budget, short-term, medium-term and long-term bridge replacement plans shall be established based on the priority of the target roads in principle, however, the other factors such as traffic safety, durability of bridges and influence of the regional development shall be taken into consideration. Bridge is a part of roads and road networks are an essential infrastructure for the regional development; therefore bridges shall not be improved independently. The target bridges allotted to each term shall be determined taking into consideration the following conditions;

1) Priority of the target roads
2) Priority group of the target roads
3) Durability of bridge taking into account the traffic safety
4) Imperfection of bridge functions including one lane carriage way on the two lane road as a parts of the road.

**(1) Short-term Plan**

The bridges in Group 1 and 2 are recommended as first priority for improvement in the short-term plan. Considering the priority of the target roads, the target roads with high priority above 20 will be recommended as the second priority group of the target roads for the short-term plan.

**(2) Medium-term Plan**

All of the remaining temporary bridges not included in the short-term plan shall be replaced to permanent structures in the medium-term plan.

**(3) Long-term Plan**

There are lots of concrete bridges including bridges inundated by flood water on the target roads. These concrete bridges were constructed within 20 years by the Cambodia and they have higher durability compared to the temporary bridges. However, the majority of the concrete bridges have only one-lane carriage way and are prone to traffic accidents on the two-lane road. Therefore they shall be replaced in the long-term plan.

Based on the above concepts, the implementation program for each category of roads is examined taking into consideration the available funds. The implementation program and project cost in each term are shown in Table 10-2.

**Table 10-2 Implementation Program of concept and budget**

| Term | Classification | Budget of Bridge Construction (Mill USD) | Cost of Bridge Replacement (Mill USD) |
|---|---|---|---|
| Short-term (2013-2017) | First Priority Group of Temporary Bridges<br>Second Priority Group of Temporary Bridges | 374 | 62 |
| Medium-term (2018-2022) | All of the remaining of Temporary Bridges | 430 | 36 |
| Long-term (2023-2027) | Concrete one lane brdiges and bridges over flow by flood water | 430 | 60 |

## 10.3 Allocation Plan

The target bridges on the road selected according to each term are shown in Table 10-3. The costs are not include administration and supervising fee.

## Table 10-3 Road List for Each Term

| Short term Plan (2013-2017) | | | | Medium term Plan (2018-2022) | | | | Long term Plan (2023-2027) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Pri. No.** | **Road No.** | **Number of Bridge** | **Cost (USD)** | **Pri. No.** | **Road No.** | **Number of Bridge** | **Cost (USD)** | **Pri. No.** | **Road No.** | **Number of Bridge** | **Cost (USD)** |
| 1 | 11 | 2 | 4,233,259 | 21 | 156 | 2 | 2,508,170 | 4 | 42 | 5 | 2,075,615 |
| 2 | 73 | 6 | 14,441,352 | 22 | 154 | 3 | 1,920,452 | 8 | 279 | 8 | 13,267,699 |
| 3 | 314D | 1 | 508,472 | 23 | 266C | 1 | 1,238,966 | 10 | 155 | 1 | 270,369 |
| 4 | 42 | 1 | 320,747 | 24 | 136 | 1 | 432,683 | 11 | 2620 | 2 | 1,118,346 |
| 5 | 267 | 1 | 397,524 | 25 | 154B | 1 | 421,153 | 15 | 277 | 2 | 456,582 |
| 6 | 2624 | 1 | 2,733,221 | 26 | 155B | 3 | 1,682,216 | 17 | 375 | 1 | 302,138 |
| 7 | 70 | 2 | 4,014,307 | 27 | 371D | 1 | 727,617 | 21 | 156 | 2 | 902,923 |
| 8 | 279 | 1 | 3,170,040 | 28 | 380A | 1 | 512,589 | 24 | 136 | 1 | 710,051 |
| 9 | 151B | 4 | 2,175,579 | 29 | 152H | 1 | 532,083 | 30 | 156D | 1 | 331,552 |
| 10 | 155 | 6 | 2,429,494 | 30 | 156D | 3 | 2,275,653 | 32 | 317C | 1 | 277,383 |
| 11 | 2620 | 1 | 2,863,869 | 31 | 155A | 1 | 842,998 | 36 | 137 | 4 | 1,264,209 |
| 12 | 314C | 1 | 1,033,501 | 32 | 317C | 1 | 284,707 | 37 | 266 | 2 | 612,389 |
| 13 | 377 | 12 | 13,371,630 | 33 | 46 | 4 | 2,849,674 | 39 | 154C | 1 | 282,872 |
| 14 | 264C | 2 | 821,664 | 34 | 159B | 1 | 965,935 | 47 | 265C | 2 | 1,605,006 |
| 15 | 277 | 2 | 1,447,291 | 35 | 2646 | 2 | 1,147,574 | 51 | 152D | 1 | 286,405 |
| 16 | 316A | 1 | 591,837 | 36 | 137 | 1 | 307,306 | 49 | 62 | 1 | 1,162,255 |
| 17 | 375 | 3 | 1,773,503 | 37 | 266 | 1 | 664,991 | 50 | 68 | 1 | 1,531,698 |
| 18 | 373B | 1 | 316,660 | 38 | 53A | 1 | 1,517,518 | 53 | 260 | 1 | 1,394,613 |
| 19 | 372A | 5 | 2,452,042 | 39 | 154C | 1 | 300,292 | 54 | 159D | 1 | 689,212 |
| 20 | 373D | 10 | 3,301,477 | 40 | 154E | 2 | 955,418 | 55 | 313 | 3 | 2,697,651 |
| | | | | 41 | 154F | 4 | 1,548,199 | 56 | 67 | 1 | 965,660 |
| | | | | 42 | 155E | 1 | 621,290 | 57 | 261 | 2 | 1,662,787 |
| | | | | 43 | 265 | 1 | 504,954 | 58 | 147 | 4 | 1,366,151 |
| | | | | 44 | 383 | 5 | 5,139,521 | 59 | 156A | 4 | 2,722,476 |
| | | | | 45 | 374 | 2 | 1,248,338 | 60 | 114 | 1 | 829,746 |
| | | | | 46 | 53B | 2 | 598,473 | 61 | 130 | 6 | 3,321,534 |
| | | | | 47 | 265C | 1 | 2,158,379 | 62 | 154A | 5 | 1,493,262 |
| | | | | 48 | 265E | 1 | 298,927 | 63 | 135 | 1 | 277,443 |
| | | | | 51 | 152D | 2 | 1,462,730 | 64 | 157C | 1 | 327,164 |
| | | | | 52 | 152F | 1 | 340,081 | 65 | 129C | 1 | 329,860 |
| | | | | | | | | 66 | 129 | 1 | 632,205 |
| | | | | | | | | 67 | 136A | 3 | 1,673,221 |
| | | | | | | | | 68 | 157B | 2 | 747,750 |
| | | | | | | | | 69 | 134B | 2 | 638,105 |
| | | | | | | | | 70 | 266E | 3 | 1,517,596 |
| | | | | | | | | 71 | 317B | 1 | 274,648 |
| | | | | | | | | 72 | 153 | 1 | 494,796 |
| | | | | | | | | 73 | 268B | 2 | 718,247 |
| | | | | | | | | 74 | 133A | 2 | 688,212 |
| | | | | | | | | 75 | 314 | 1 | 581,047 |
| | | | | | | | | 76 | 387A | 1 | 447,439 |
| | | | | | | | | 77 | 153C | 1 | 550,038 |
| | | | | | | | | 78 | 313A | 1 | 288,961 |
| | | | | | | | | 79 | 387 | 2 | 769,979 |
| | | | | | | | | 80 | 152G | 1 | 302,540 |
| | | | | | | | | 81 | 121 | 1 | 322,796 |
| | | | | | | | | 82 | 153B | 2 | 965,145 |
| | | | | | | | | 83 | 152 | 1 | 291,596 |
| | | | | | | | | 84 | 265B | 2 | 1,019,153 |
| First Priority Group | | | 50,655,371 | | | | | 85 | 268A | 5 | 1,458,016 |
| Second Priority Group | | | 11,742,098 | | | | | 86 | 156C | 2 | 1,090,373 |
| **Total Cost (USD)** | | | **62,397,469** | **Total Cost (USD)** | | | **36,008,887** | **Total Cost (USD)** | | | **60,006,914** |

# 11. CONCLUSIONS AND RECOMMENDATIONS

## 11.1 Conclusions

### (1) General

In this project, 1205 bridges on 168 roads including 2-, 3- and some 4-digit roads administrated by the MPWT and the MRD have been investigated through this project. Many bridges on the road have been improved with permanent bridges by the Government of Cambodia and with support of donor countries and agencies. On the other hand, 200 bridges which need to be replaced with permanent bridges still remain on the road. Failure of such inferior bridges on the road will cause serious damage to the economy of the society as analyzed in this report.

### (2) Temporary Bridges Requiring Replacement

The temporary bridges including wooden bridges, temporary steel bridges, temporary concrete bridges and bridge with grade three deficiency require the most urgent replacement because of their vulnerability to modern traffic. Bailey bridges have some strength for the traffic because they are designed for the emergency opening of roads in the event of war. However the Bailey bridges are designed for temporary use and they do not have enough durability over long periods. There are lots of one-lane concrete bridges which have been constructed by the Cambodia. The majority of them are constructed within 20 years and have some strength for the existing traffic, however as roads are improved to two traffic lanes, the one-lane bridges hinder modern traffic and cause traffic accidents.

The bridges on the roads which shall be replaced with permanent bridges and the degree of urgency for their replacement are as follows:

1) Temporary bridges including Bailey bridge, wooden bridge and others.
2) Bridges with insufficient bridge opening, i.e. the bridges that suffer with flood water.
3) Bridges with insufficient carriageway width compared to road way width.

## 11.2 Recommendation

### (1) Priority Setting for the Replacement of the Temporary Bridges

The temporary bridges and bridges with insufficient bridge functions shall be replaced to permanent bridges with sufficient functions. However, there are budget constraints to carrying out the replacement of all bridges on roads. The bridges shall be replaced in accordance with the priority of bridges which was designated in Chapter 10.

### (2) Establishment of Data base system for Bridge Maintenance

The bridges nominated in this project are only a part of bridges in Cambodia. There are lots of bridges still remaining unimproved in local areas and they are an important infrastructure for the development of the region. A bridge data system including inventory system and inspection system shall be developed for the reasonable and systematic approach to improve large number of inferior bridges.

### (3) Development of Construction Companies in Cambodia for Bridge Construction

The construction companies in Cambodia do not have enough capability for bridge construction yet, however there are modern bridges that were constructed by the Cambodian army. The bridges have enough durability for existing traffic load. The bridge construction technology owned by the Cambodian army and foreign contractors shall be transferred to the private construction companies in Cambodia.

### (4) Introduction of Modern Construction Technology

The majority of bridges constructed by Cambodian people are reinforced concrete bridges. They are constructed by very conventional methods and they have some limitations regarding the scale of bridge including its span length. Some modern construction technologies including pre-stressed concrete shall be introduced through a pilot project as new technologies for Cambodia.

### (5) Implementation of Preventive Bridge Maintenance

As recommended in the Section 6 Economic Evaluation, inferior bridges shall be replaced under a preventive maintenance plan. Once a bridge is closed to the traffic, the loss for regional economy and traffic on the road is unbearably big. The economic benefit of bridge replacement by the preventive maintenance plan compared to the breakdown maintenance is obvious.

**(6) Establishment of an Emergency Bridge Opening Unit.**

There are still a lot of temporary bridges on roads in Cambodia for the time being. As described in Chapter 6, closure of the road to the traffic causes a severe loss for the regional economy. The cost if traffic loss increases as the closed time grows. The emergency bridge opening unit, which keeps several sets of Bailey bridges for emergency opening in the event of bridge failure, is very effective for opening the traffic within a short time period.

Following actions are recommended to maintain all remaining inferior bridges.

1) Establish database system for all road infrastructures.
2) Establish a bridge management system including bridge inventory and inspection...
3) Improve the capacity of bridge maintenance as recommended in Package B of this project.
4) Raising private construction company.
5) Introduce modern bridge technology including bridge design and construction
6) Replace inferior bridges before closing traffic due to the bridge failure.
7) Establish an emergency bridge opening unit within the MPWT and MRD.

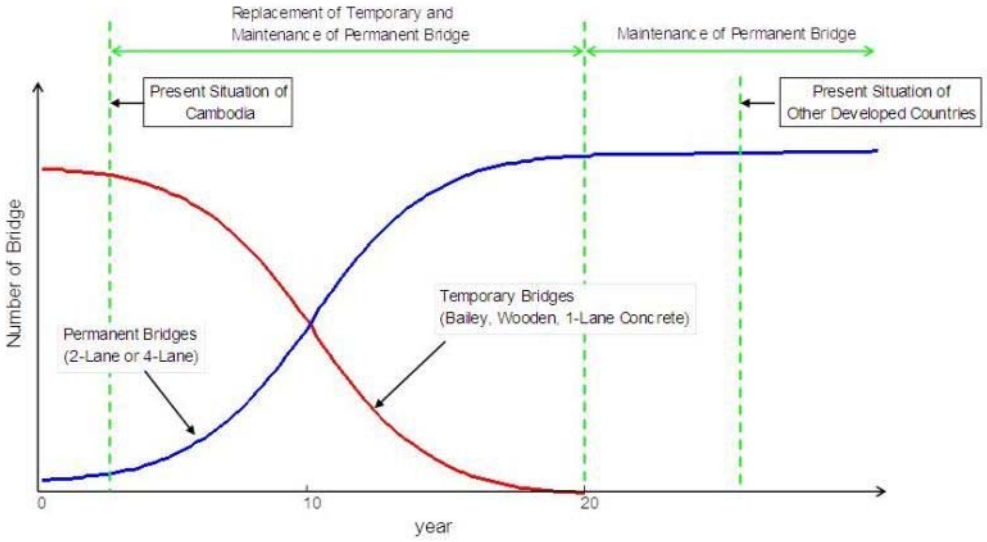
# 12. BRIDGE MAINTENANCE (PACKAGE B)

## 12.1 Bridge Maintenance

### (1) Existing Condition of Bridge Maintenance

Many temporary bridges still remain in Cambodia and they need to be replaced with permanent bridges. However, certain years are required to replace the temporary bridge to permanent bridges completely because of limited budget. There are some needs to maintain the temporary bridges until they are replaced with the permanent bridge and to prioritize the replacement of temporary bridges.

Status of the bridges replacement in Cambodia is shown in Figure 12-1.



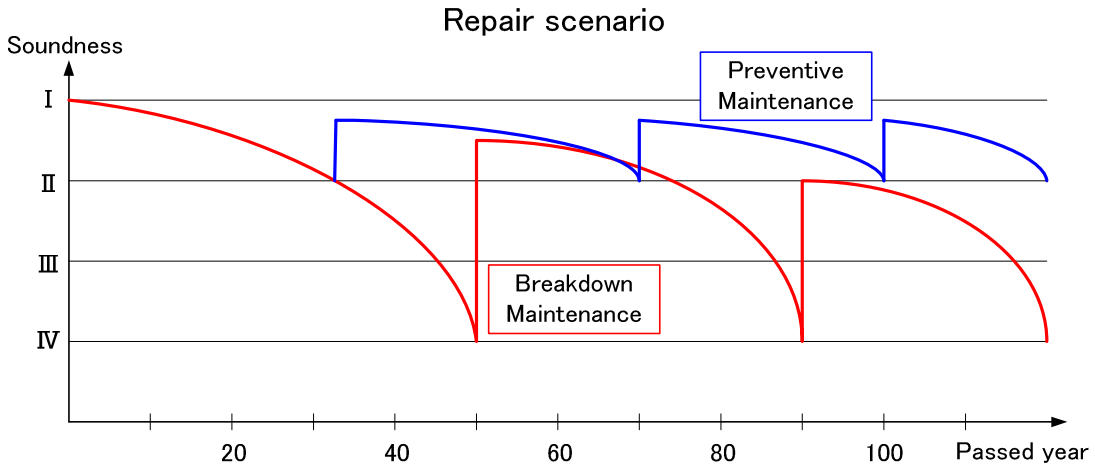

Source: Study Team

**Figure 12-1 Correlation between Replacement and Maintenance of Bridges**

### (2) Management of Temporary and Permanent Bridges

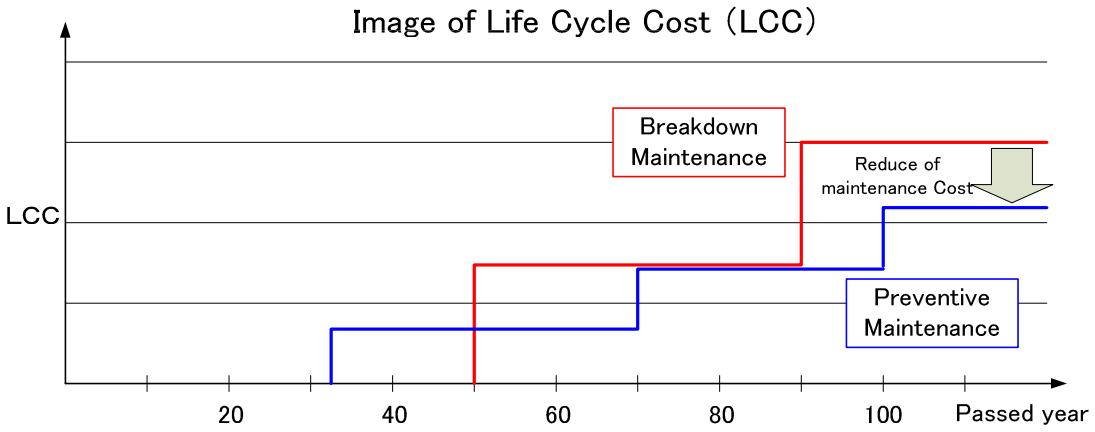
Bridges are an important asset of the nation and the most expensive facilities on roads. Car owners always maintain their cars as long as possible considering the life cycle cost until the maintenance cost surpasses the cost of a new car. The same as above, bridges shall be maintained as long as possible considering the life cycle cost of the bridge. The budget for the social infrastructure could be reduced by the adoption of the concept of life cycle cost.

Figure 12-2 and Figure 12-3 show the image of the life cycle cost for the reduction of total cost of a bridge by using maintenance activities. Figure 12-3 shows the comparison of the life cycle cost between the cost of a bridge with frequent maintenance and one with long interval maintenance. The relationship between interval of repair and repair cost shall be studied.




Source: Study Team

**Figure 12-2 Repair Scenarios**




Source: Study Team

**Figure 12-3 Image of Life Cycle Cost**

### (3) Organization related to Bridge Maintenance in Cambodia

The Ministry of Public Works and Transport (MPWT) is responsible for management and maintenance of national roads. However, provincial roads are also managed by the Ministry of Rural Development (MRD). Jurisdiction on management of those roads between the MPWT and the MRD is not clear because the present system.

Department of Road Infrastructure (RID), Heavy Equipment Center (HEC), Department of Sub-National Public Infrastructure and Engineering (SPIED) and Public Works Research Center (PWRC) under the General Directorate of Public Works in the MPWT relate to bridge management.

The Department of Investment and Cooperation in the Ministry of Economy and Finance (MEF) is in charge of the management of public investment and setting priority for annual investments in order to budget in cooperation with the relevant ministries.

The Inter-Ministerial Coordination Committee (IMCC) was established on 2006 for evaluation of maintenance program and smooth maintenance activities of roads and bridges. Member consists of the MEF and the MPWT.

### (4) Institution related to Bridge Maintenance

Based on the Law on Road Traffic, inspection of overloaded vehicles are implemented at 9 fixed weigh stations on 1-digit roads by the MPWT and Police. 38 mobile portable weight scales are also provided by the MPWT to cover 2-digit and 3-digit roads. Of 38, only 18 are operable.

### (5) Budgeting System

The financial year in Cambodia starts in January and closes in end of December. In order to obtain the road maintenance budget, the MPWT prepares the Routine Maintenance Program, showing the requested amount of maintenance funding and its breakdown and then negotiates with the MEF.

Figure 12-4 shows the flow of budget approval and implementation of maintenance.

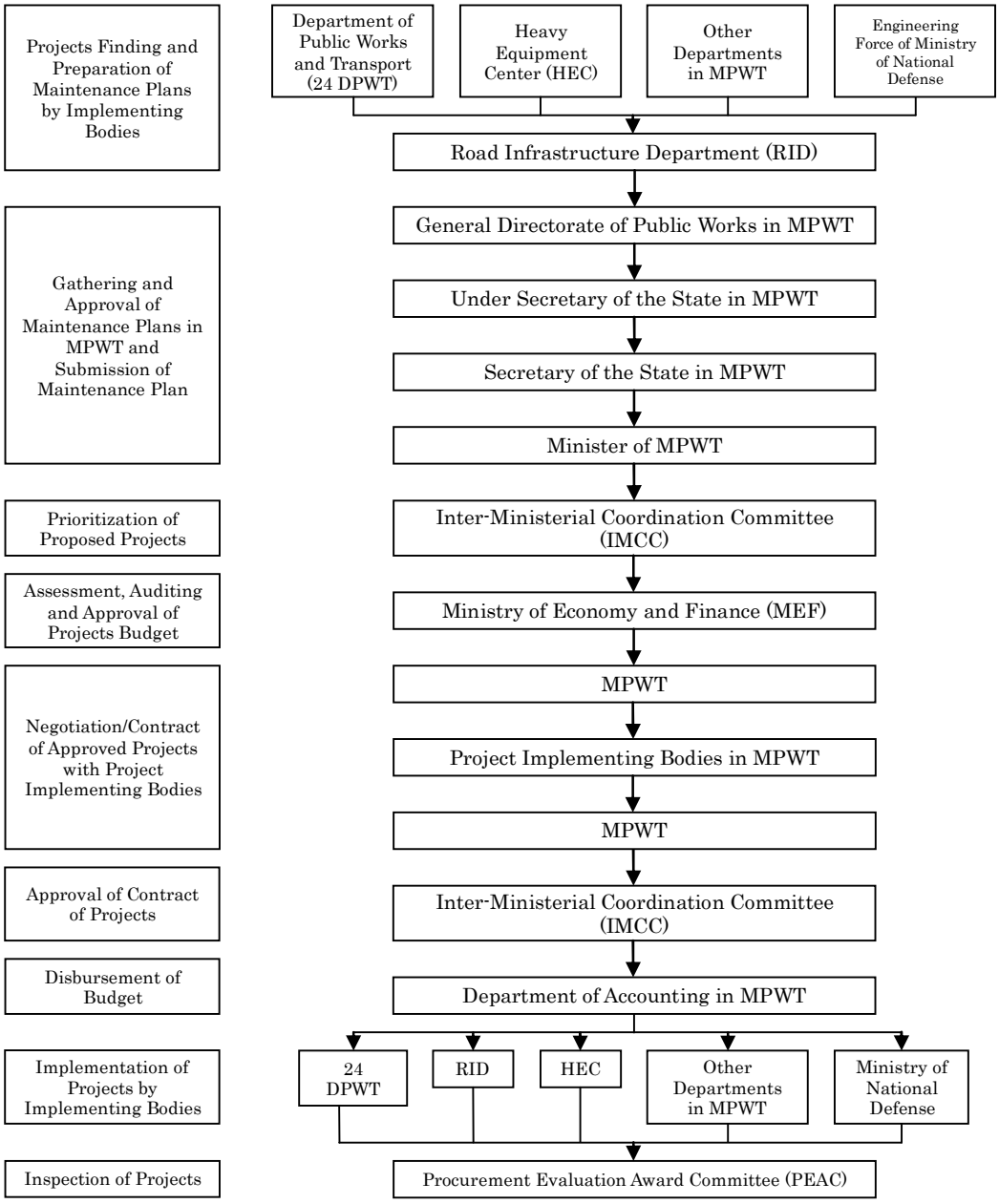



**Figure 12-4 Flow of Budget Approval and Implementation of Bridge Maintenance**

## 12.2 Problems and Issues on Bridge Maintenance

Following are problems on Road and Bridge Maintenance. Problems can be classified into 6 fields – condition of roads and bridges, organization, inspection technology, information and data, human resource, and others.

**Table 12-1 Problems on Road and Bridge Maintenance**

| Fields | Problems |
|---|---|
| Condition of Roads and Bridges | ・ Only minor repair works of bridges is carried out.<br>・ Replacement of bridges are put higher priority than repair works.<br>・ Budget for bridge maintenance is low.<br>・ Condition of bridges especially temporary bridges is not good. |
| Organization | ・ RID, HEC and each DPWT construct roads and bridges.<br>・ Each DPWT carries out regular inspection of roads and bridges.<br>・ RID and HEC conduct a detailed survey and planning of repair based on an inspection result.<br>・ Organization responsible for construction, investigation and repair has not been established.<br>・ Information and data of constructed roads and bridges have not been managed by one organization in the MPWT.<br>・ Only about 60% of proposed projects were approved by MEF.<br>・ The MPWT and DPWTs have maintained all of national and provincial roads and bridges on the roads except National Road NO 4. |
| Inspection Technology | ・ Only visual inspection has been carried out.<br>・ Inspection result has been taken note.<br>・ A common inspection sheet has not been developed.<br>・ Inspection result/data has not been kept and not recorded.<br>・ No guideline and manual for inspection and repair has been developed.<br>・ Inspection work is not understood well.<br>・ Training of inspection work has not been done. |
| Information and Data | ・ RID and HEC have a different roads and bridges list.<br>・ Items and contents of the list are different.<br>・ Number of bridges in the list is different.<br>・ Data of the list is old and information on condition is not explained properly.<br>・ Form of the list is different.<br>・ No network has been developed for access to the list. |
| Human Resource | ・ Staff having knowledge, skill and experience of inspection is very few.<br>・ Number of staffs in each DPWT decreases.<br>・ Many staffs in the MPWT and DPWTs do not get enough salary.<br>・ Less number of university students wants a job in a public sector.<br>・ Less number of high-school students wants to go enter engineering universities and engineering departments in universities.<br>・ Tuition fee of universities and departments of engineering is higher than others.<br>・ No scholarship system is provided by the government.<br>・ Course contents on structure lessened in the university is old.<br>・ Classroom hour on structure is less.<br>・ Teachers have jobs other than an university. |
| Others | ・ Taxes founded and collected for road and bridge maintenance have not been used not only for the maintenance but also other purposes.<br>・ Rate of taxes is rather low.<br>・ Regulatory work against overloaded vehicles is lax.<br>・ Overloaded vehicles avoid measuring points.<br>・ Measuring points of overloaded vehicles are 7 in Cambodia.<br>・ Collapse of bridges has been occurred by overloaded vehicles. |

Source: Study Team

## 12.3 Capacity Development of Bridge Maintenance

### (1) Program/Projects and Rough Schedule

Following 4 projects (project purposes) and 10 sub-projects (project activities) are proposed based on analysis of problems and objectives to achieve the program purpose that "Roads and Bridges managed by the MPWT are maintained properly."

**Table 12-2 Program/Projects and Rough Schedule**

| Program Purpose | Project Purpose | Project Activities | Agency Responsible | Before the Project | Short 3 years | Middle 5 years | Long 5 years |
|---|---|---|---|---|---|---|---|
| Proper maintenance of bridges managed by the MPWT | Strengthening of capacity on bridge maintenance of the MPWT | Strengthening of organization for maintenance | MPWT & DPWT | | ■ | | |
| | | Development of technology of maintenance | | | ■ | | |
| | | Improvement of capability of engineers on maintenance | | | ■ | ■ | ■ |
| | | Establishment of maintenance management system | | | ■ | ■ | ■ |
| | Securing of sufficient budget for road and bridge maintenance | Finding of funding source for road and bridge maintenance | MEF | | ■ | | |
| | Compliance of law/regulation on road traffic | Strengthening of regulatory work and penalty against overloaded vehicles | Police and MPWT | | ■ | ■ | ■ |
| | | Implementation of awareness activity to truck operators | | | ■ | ■ | ■ |
| | Increase of number of engineers having enough knowledge and skill | Increase of number of high school students going to engineering universities | MEYS, MLVT, University and MPWT | | ■ | ■ | ■ |
| | | Enhancement of class in universities | | | ■ | ■ | ■ |
| | | Increase of attractiveness of job in public sedtor | | | ■ | ■ | |

Source: Study Team

### (2) Selection of the Capacity Development Project

The MPWT, the MEF, Police and other organizations are expected to be implementation bodies of 4 projects to achieve the Program. The MPWT is a main target organization of the capacity development project. Therefore, the project that "Strengthening of Capacity on Bridge Maintenance of the MPWT" is the most appropriate for capacity development of the MPWT. This project consists of following 4 sub-projects.

1) Strengthening of Organization for maintenance
2) Development of Technology of Maintenance
3) Capability Improvement of Engineers on Maintenance, and
4) Establishment of Maintenance Management System

Remaining projects are also very important to achieve the program purpose. Cambodian government should implement these projects at the same time.

### (3) Strengthening of Organization for maintenance

A maintenance organization should be the actual implementation body of the next capacity development project. Strengthening of the organization and improvement of the

maintenance technology of engineers in the organization should be carried out through the project. This organization should also be responsible for continuous maintenance after the project. Unfortunately, however, no independent or special department or section for maintenance exists in the MPWT and DPWTs. Therefore, a project management unit (PMU) should be organized prior to the project implementation. Followings will be carried out in the project.

1) Discussion and decision of roles, responsibility and authority of the organization responsible for road structures maintenance
2) Study and decision of the maintenance organization in the DPWT, and
3) Approval of role, responsibility and authority by the MPWT

### (4) Development of Technology of Maintenance

No guideline or manual has been developed in Cambodia yet. Therefore, the guideline and the manual should be developed at an early stage in the project. Nine (9) large scale bridges across the Mekong and other big rivers have been constructed recently. Inspection points and inspection precaution are different depending on size and type of a bridge. Therefore, a manual for large scale bridges should also be provided by type after development of the comprehensive manual in the project.

Followings will be conducted for development of maintenance technology.

1) Development of a guideline and a manual of bridge maintenance
2) Development of a manual for large scale bridges inspection, and
3) Provision of necessary tools for bridge inspection

### (5) Capability Improvement of Engineers on Maintenance

Engineers involved in maintenance works of road structures in the MPWT and 24 DPWTs have inadequate knowledge and skill on maintenance works. Training for them is indispensable for continual proper maintenance of bridges. Training will be carried out in a room and at sites. Training for all engineers involved in maintenance works of bridges in the MPWT and DPWTs during the project period is difficult because of the limitations of duration, budget and number of experts inputted. Therefore, capability development of engineers in the MPWT and DPWTs should be implemented in two different stages as follows.

| Training Stage | | Target of Training |
|---|---|---|
| At the Project | : | Engineers in the MPWT and some selected DPWTs |
| After the Project | : | Engineers in remaining DPWTs |

Followings activities will be implemented for capability improvement of engineers on maintenance.

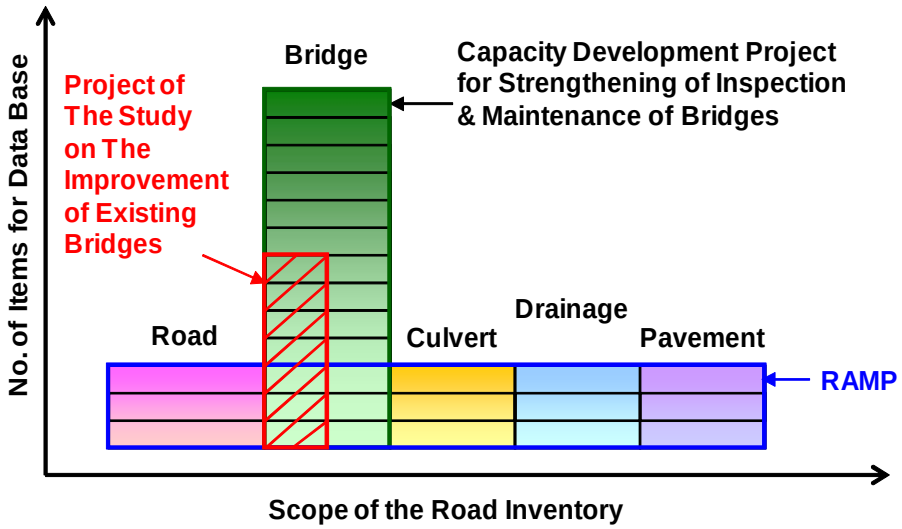
1) Development of training material, planning of the training schedule and the monitoring
2) Selection and training of trainees (engineers) of the MPWT and DPWTs
3) Implementation and monitoring of the pilot project
4) Overseas Training
5) Establishment of Qualification System, and
6) Exchange of information with developed countries

### (6) Establishment of Maintenance Management System

Bridge management system (BMS) is roughly classified into two parts. One is the database and the other is evaluation and planning method.

However, no database has been developed yet. Sufficient and correct data and information on bridges are not collected. Inspection data has not been recorded and stored. Documents related to maintenance have not been managed adequately. The database is a keystone of the system. Therefore, the database especially bridge inventory data should be collected and compiled at first in the project.

Data for roads and bridges maintenance is now being collected by two projects, "The Study on the Improvement of Existing Bridges" by JICA and RAMP by WB and others. However, data collected at two projects is not sufficient for the inventory from type of data and number of bridges and items point of view. Therefore, the inventory should be developed in the project at first.




Source: Study Team

**Figure 12-5 Image of Data Collection on Road Assets by Project**

Following activities will be implemented for establishment of database.

1) Confirmation of existing information and data of bridges
2) Examination of network environment and proper components
3) Preparation of equipment
4) Development of the database
5) Study of method for evaluation, prioritization, and cost estimation of repair for establishment of the bridge management system in future
6) Development of database manual, and
7) Seminar

### (7) Expected Team Members and Man-Month

Expected team members of experts and counterparts are 7 and 20 respectively. Total man-months of experts and counterparts required for project implementation are 95 and 188.

**Table 12-3 Team Members**

| Experts | Counterparts |
|---|---|
| ・ A chief advisor<br>・ A bridge maintenance engineer<br>・ A road maintenance engineer<br>・ An organization analyst<br>・ A bridge database engineer<br>・ Two Bridge inspectors (Trainers) | ・ A director<br>・ A deputy director<br>・ Two Bridge engineers from MPWT<br>・ Two road engineers from MPWT<br>・ Four engineers as an inspector from the MPWT<br>・ Eight engineers as an inspector from DPWTs<br>・ Two IT specialists from MPWT |
| Total: 7 members/95 man-months | Total: 20 members/188 man-months |

Source: Study Team