MAINTENANCE SUSTAINABILITY ANALYSIS

1. The Project will finance the periodic maintenance or rehabilitation of about 1,000 km highways (890 km under output 1 and 112.8 km under output 2). In order to increase the effect of the Project on the sustainability of the road network, a network-level strategy analysis was carried out using the Highway Design and Management IV (HDM-IV) software to assess the sustainability of the network maintenance and advise on the optimal maintenance strategy.

A. Data Analysis

2. Data regarding the highway network in Yunnan is currently spread over three databases: (i) a database covering the geometric data and other main characteristics of the different roads, (ii) a traffic database with data from the different survey stations, and (iii) the road condition database with survey data collected by YSRI. To effectively use this data for the HDM-IV assessment, these different data sets were merged into one single database. This was done for the 2010 data, and the database was subsequently updated with data from 2011.

3. The resulting database showed a network of 24,585 km (21% national highways, 55% provincial highways and 24% county roads)[1]. Traffic data was available for 19,518km (79% of the network), and condition data was only available for 13,722km (56% of the network). To facilitate the analysis using HDM-IV, the roads were categorized according to road class (C1-C5), surface type (P1-P4), traffic volume (T1-T4, according to the Average Daily Traffic – ADT) and road condition (R1-R4 based on the international roughness index – IRI).

Table 1: Road class categories

Category		km	%
C1	Class I	238	1%
C2	Class II	5,761	23%
C3	Class III	6,069	25%
C4	Class IV	11,276	46%
C5	Under class	1,241	5%
	Total	**24,585**	**100%**

Source: PPTA Consultant processing of YHAB data.

Table 2: Road surface categories

Category		km	%
P1	Asphalt Concrete	12,504	51%
P2	Simple Pavement	8,676	35%
P3	Cement Concrete	457	2%
P4	Unpaved	2,942	12%
	Total	**24,585**	**100%**

Source: PPTA Consultant processing of YHAB data.

Table 3: Traffic volume categories

Category		km	%
T1	ADT≤1000	6,901	35%
T2	1000<ADT≤2000	5,632	29%
T3	2000<ADT≤4000	3,859	20%
T4	ADT>4000	3,126	16%
	Total	**19,518**	**100%**

Source: PPTA Consultant processing of YHAB data.

Table 4: Roughness categories

Category		km	%
R1	IRI≤3.5	2,588	19%
R2	3.5<IRI≤5	4,197	31%
R3	5<IRI≤7.5	4,488	33%
R4	IRI>7.5	2,449	18%
	Total	**13,722**	**100%**

Source: PPTA Consultant processing of YHAB data.

4. Each combination of categories results in a specific case: a set of road sections with the same specific class, surface type, traffic volume and roughness (e.g. T1C2R1P1). Based on the available data for the road network, the total road length in each case was estimated through simple linear extrapolation. Given the small length of cement concrete roads and the fact that unpaved roads are likely to be paved in the near future, this exercise was done only for the network with bituminous paving (asphalt concrete or simple pavement). The 2010 official length of the bituminous network is 19,652km. The road length for each case is presented in Table 5.

[1] This is slightly different from the official statistics of 23,277km in 2010 and 24,089km in 2011. This is most likely due to overlapping roads that have not been properly identified in the database.

Table 5: Description of cases (km)

		R1		R2		R3		R4		Total
		P1	**P2**	**P1**	**P2**	**P1**	**P2**	**P1**	**P2**	
T1	**C1**	3	0	20	0	25	0	2	0	**51**
	C2	391	0	59	7	44	3	37	2	**543**
	C3	39	52	149	249	189	303	76	289	**1,347**
	C4	237	169	907	381	1,115	489	261	435	**3,993**
	C5	0	0	19	0	32	7	0	32	**90**
T2	**C1**	0	0	0	0	0	0	0	0	**0**
	C2	531	0	223	0	171	0	24	0	**949**
	C3	69	78	186	257	222	239	37	340	**1,428**
	C4	151	74	531	371	621	428	254	552	**2,981**
	C5	0	0	0	5	29	10	3	0	**47**
T3	**C1**	3	0	19	0	7	0	0	0	**29**
	C2	575	78	362	61	206	7	27	0	**1,316**
	C3	37	85	132	325	96	572	12	371	**1,629**
	C4	24	46	345	200	264	269	74	178	**1,399**
	C5	2	0	10	0	12	0	2	0	**25**
T4	**C1**	71	0	22	0	7	0	0	0	**100**
	C2	594	3	477	2	350	3	83	3	**1,516**
	C3	66	171	129	189	137	298	54	271	**1,315**
	C4	7	137	54	250	117	196	14	118	**893**
	C5	0	0	0	0	0	0	0	0	**0**
Total		**2,800**	**893**	**3,644**	**2,296**	**3,644**	**2,824**	**959**	**2,590**	**19,652**

Source: PPTA Consultant processing of YHAB data.

5. It is immediately obvious that some cases have very long road lengths, while others have no or very few roads. This allowed less important cases to be grouped together with more important cases (underlined in the table), reducing the number of cases from the original 160 to 38. These 38 cases were subsequently analyzed using HDM-IV (see section C).

6. Further analysis of the traffic data showed that class I and II roads predominantly have high traffic volumes (T3 and T4) and class IV and underclass roads mainly have low traffic volumes (T3 and T4), with class III roads having a quite even distribution of traffic volumes. What was surprising was that a large percentage of class I roads (28%) and a significant percentage of class II roads (17%) had very low traffic volumes (T1). This analysis also showed that increased traffic volumes tended to have a higher percentage of passenger cars and a lower percentage of utility vehicles (pickups and small trucks) as well as a slightly lower percentage of larger trucks.

7. Data on overloading was unfortunately not available. However, a simulation carried out on existing traffic volumes and make-up assuming 30% overloading in 30% of the trucks, resulted in cumulative Equivalent Standard Axle Loads (ESAL) per year of 3.7 million for T4, 1.5 million for T3, 0.8 million for T2 and 0.3 million for T1. This should be compared to the standard design for class II roads that assumes an accumulation of 10 million standard axle loads during the expected design life of 12 years. It is evident that in case of overloading, this design life will only be realized for low traffic volumes (T1 or T2) and that for higher traffic volumes (T3 or T4) the lifespan of such a pavement will be reduced to respectively 6.5 or 3 years. The significant impact of overloading on the pavement life is evident in many of the highways in Yunnan that fail prematurely.

8. Further analysis regarding road conditions showed that roughness tends to be lower in class I and II roads where the majority is in R1 or R2. Roughness also tends to be lower in

roads with higher traffic volumes, especially in terms of more R1 roads and fewer R4 roads (the percentage of R2 and R3 roads remains fairly constant). Asphalt concrete and cement concrete roads tend to have a lower roughness (majority of roads in R1 or R2) than roads with a simple pavement and unpaved roads (majority of roads in R3 and R4).

9. An analysis of visual distress shows more cracks and raveling in roads with high traffic volumes (T4) and with simple pavement. Patching, however, is higher in case of asphalt concrete pavement, as well as for roads with high traffic volumes, indicating more minor maintenance being carried out in these roads. Surprisingly, the distress levels remain low even in roads with very high roughness, indicating excessive attention to minor maintenance where intermediate or even heavy maintenance is required.

10. The annual volume of resurfacing was also analyzed. Given the fact that resurfacing is carried out by different entities besides YHAB (e.g. YPDOT, YHIC, prefecture governments, county governments) and that proper data was not available, the length of resurfacing was calculated using the road statistical data: (i) on the basis of the year of construction or rehabilitation as indicated in the database (although this was not always considered correct), and (ii) on the basis of the current roughness or the road network. The database shows a total of approximately 10,700km of rehabilitation carried out in the past 10 years, implying an average resurfacing of 1,000km per year. Analysis of roughness data, on the other hand, shows 3,700km of roads with an IRI of less than 3.5. Taking into account the traffic levels on these roads and the pavement evolution deducted by comparing the 2011 and 2010 condition data, this would indicate an average resurfacing of approximately 700 km per year. For purposes of this analysis, the lower amount of 700km has been used.

11. Not all the resurfacing works have been carried out by YHAB, however, and a considerable portion is likely to have been carried out by YPDOT, YHIC or local governments and subsequently transferred to YHAB. Based on the reported intermediate and heavy maintenance works carried out by YHAB (an average of 250 km in 2010 and 2011), it is assumed that on average 450km per year is resurfaced by other entities than YHAB.

B. Road Maintenance Funding

12. The HDM-IV software also requires an estimation of the available maintenance budget in order that it can determine the most optimal use of that budget and the resulting road conditions. Detailed funding and expenditure data for maintenance of the highway network was obtained from YHAB for 2010 and 2011 (see Appendix 1). The funding data demonstrated the dominance of the fuel tax allocation in YHAB's maintenance budget (76% in 2011), followed by overloading fees (17%). Only a small portion of this budget is spent on intermediate and heavy maintenance (7% in 2011), with most spent on staff salaries and bonuses (34%), pensions (32%), minor maintenance (17%) and management costs (9%).

13. For each expenditure item and funding source, annual growth rates were estimated for the next 20 years (these are presents in Appendix 1). It was further assumed that in a specific year, any funds from the YHAB maintenance budget remaining after allocation to other expenditure items (taking into account their estimated growth rates), would be fully allocated to intermediate and heavy maintenance (this is what appears to be happening in practice). This allowed the funding levels for intermediate and heavy maintenance to be estimated for each year, based on current income and expenditure patterns.

14. For the HDM-IV model it was decided to test three budget scenarios. The first scenario is based on the 2011 budget allocation from YHAB for intermediate and heavy maintenance of CNY 145 million. The CNY 145 million from YHAB is allowed to vary based on expected increases in income (mainly fuel tax) and expenditure (the allocation to intermediate and heavy maintenance is defined as all remaining funding after allocation to salaries, pensions, maintenance management and minor maintenance). This scenario does not include any changes to incomes or expenditures other than expected normal growth rates. Under this scenario the allocation to intermediate and heavy maintenance was found to slowly grow from approximately CNY 200 million in 2012 to approximately CNY 400 million in 2022.

15. The second scenario assumed a gradual growth in the percentage of fuel tax allocated to YHAB from the current 27% to 32% (5% increase) over a five-year period, and subsequent fixed allocation of 32%. Under this scenario the allocation to intermediate and heavy maintenance was found to slowly grow from approximately CNY 200 million in 2012 to nearly CNY 1,000 million in 2022.

16. The third scenario went a step further and assumed a gradual increase in fuel tax allocation from 27% to 40% over five years (and subsequent fixed allocation of 40%), as well as a reduction of maintenance costs (5% reduction of management and minor maintenance costs) due to improved implementation mechanisms (outsourcing, performance-based contracts, improved technologies, newer equipment, etc.). Under this third scenario the allocation to intermediate and heavy maintenance was found to slowly grow from approximately CNY 200 million in 2012 to approximately CNY 2,000 million in 2022.

17. Based on a the analysis carried out on the road condition data, it was decided to adjust the funding scenarios to take into account the fact that the data indicated an annual average resurfacing of 450 km carried out by other entities in addition to the maintenance works carried out by YHAB. For the HDM-IV model it was therefore assumed that an additional average annual budget of CNY 550 million for intermediate and heavy maintenance from outside YHAB would be available each year (this amount was assumed to remain fixed). In all three scenarios the estimated annual budget was subsequently corrected to take account of inflation (3%). The resulting budgets are shown below (detailed data for the different scenarios is provided in the Appendix 1). Table 6 and 7 shows the intermediate/heavy maintenance budgets available to YHAB, in nominal and real terms. The budgets simulated by HDM-IV included an additional nominal CNY 550 million annual funding from sources other than YHAB.

Table 6: Estimated YHAB budgets for intermediate and heavy maintenance (CNY million)

Year	2012-2016	2017-2021	2022-2026	2027-2031
Scenario 1	1,540	1,670	3,270	5,850
Scenario 2	2,600	4,080	6,500	10,170
Scenario 3	5,480	8,780	12,750	18,490

Source: PPTA Consultant processing of YHAB data.

Table 7: Estimated YHAB budgets for intermediate and heavy maintenance (CNY million) - corrected for inflation

Year	2012-2016	2017-2021	2022-2026	2027-2031
Scenario 1	1,370	1,270	2,150	3,320
Scenario 2	2,290	3,110	4,270	5,770
Scenario 3	4,820	6,710	8,400	10,510

Source: PPTA Consultant processing of YHAB data.

18. On the cost side, the following unit prices were used for the procurement, preparation and placement of asphalt concrete, cement treated gravel and gravel. An additional 20% was added to these unit costs to cover overhead costs.

Table 8: Estimated material costs

Material	Unit cost
Asphalt Concrete	CNY 400/ton
Cement Treated Gravel	CNY 120/ton
Gravel	CNY 80/ton

Source: YHAB.

C. Road Network Condition

19. After entering the road data and other variables[2] into the HDM-IV model, it was subsequently calibrated. This was done by adjusting specific pavement deterioration variables[3] so that the modeled deterioration corresponded to the deterioration according to the data received from YHAB. This was complicated by the fact that condition data was only available for 2010 and 2011, and only for part of the network. The lack of overloading data further exacerbated this problem, as overloading has a significant effect on the pavement evolution and is often localized to particular roads. The resulting model can therefore not be seen as a perfect representation of the road network evolution in Yunnan, but only as a representation of that portion of network evolution that is visible through the provided data.

20. According to the road condition data obtained from YHAB, the baseline network condition is that only 49% of the network has an international roughness index (IRI) below 5 (considered fair or good condition). As much as 18% of the network has a roughness above 7.5 (considered very poor condition). To give a benchmark, YHAB had the lowest proportion of national roads in good condition among all PRC provinces in 2010. The national average was 78.8% of the network in good condition at the time.

21. To predict future network performance, alternative maintenance strategies were tested and compared for each of the three funding scenarios using the HDM-IV software. A strategy is a sequence of subsequent maintenance standards (different minor, intermediate and heavy maintenance interventions) applied over time. A full list of the maintenance standards applied can be found in Appendix 2. A total of 29 different strategies (8-11 strategies for each road class) were defined for HDM-IV to choose from, each with different combinations of suitable maintenance standards (a full list of strategies can be found in Appendix 3).

22. The HDM-IV software optimizes the maintenance strategy for each road case by selecting from the set of possible strategies and proposing the strategy that maximizes the economic net present value for the users (in terms of vehicle operating costs and time savings) under the selected multiannual budget constraint. That is to say that for each road case (e.g., T1C2R1P1) it will choose a particular strategy with the aim to maximize the economic net present value, taking into account that the budget may be more efficiently used for other cases where a higher net present value can be achieved at the same cost. HDM-IV therefore maximizes the total net present value to be achieved with the available budget by deciding how

[2] HDM-IV requires values to be set for a large set of variables. Due to the lack of data in Yunnan, many of these values had to be estimated based on experiences in other provinces, countries, or extrapolating from existing data sets. This was especially the case for the variables related to operating costs and time valuation.

[3] Based on the calibration process, most HDM-IV default values were retained except for Crack Initiation (Kcia), Crack Progression (Kcpa), Environmental Factor for Roughness (Kgm), and Structural Factor for Roughness (Kgs).

much budget to allocate to each case, and which strategy (combination of maintenance standards) to apply in each case. This is done for a planning period of 20 years.

23. The result is a set of strategies defined for each road case, depending on the specific funding scenario (available maintenance budget). The limited maintenance budget can result in HDM-IV recommending to apply only minor maintenance to certain roads, prioritizing funding for intermediate and heavy maintenance to other cases where the economic benefits are higher. The resulting strategies for each of the three scenarios as optimized by HDM-IV can be found in Appendix 4.

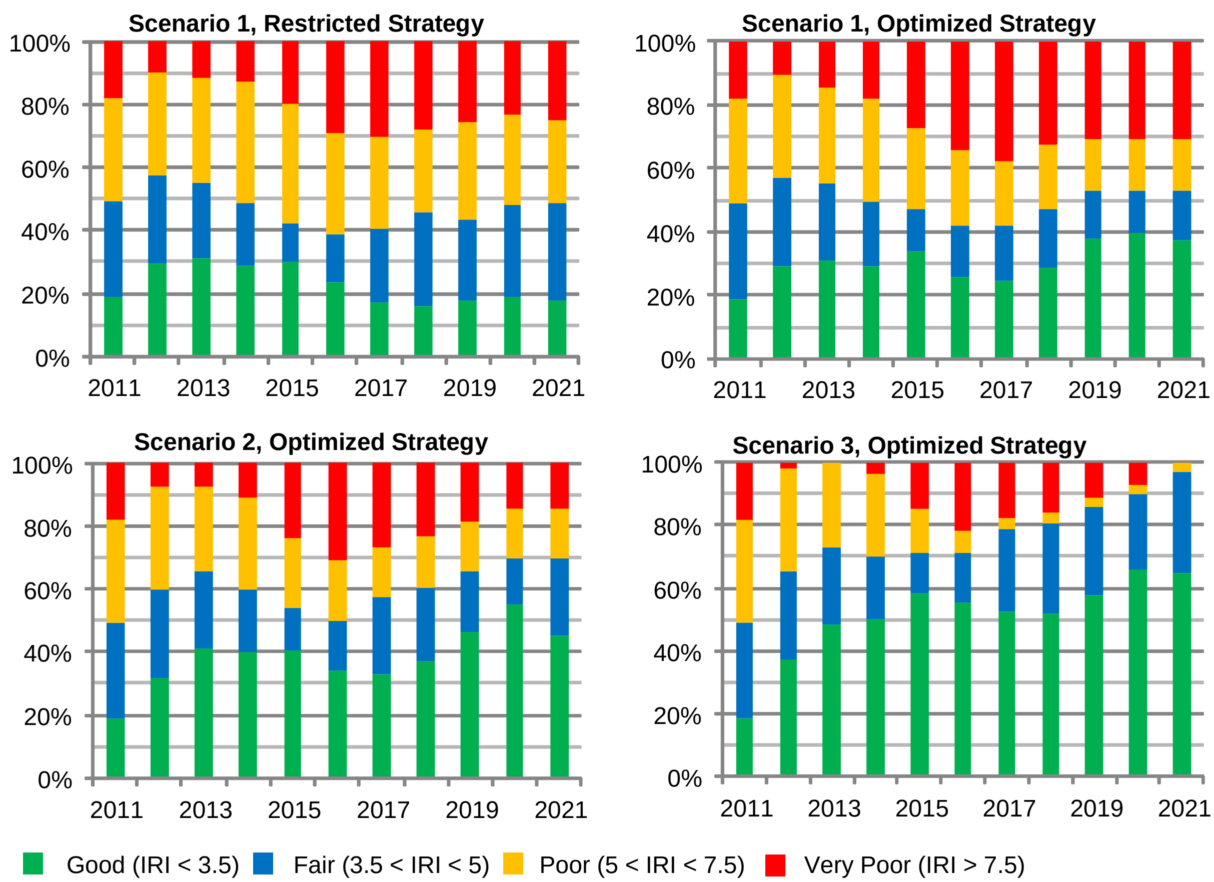
24. In addition to the optimization by HDM-IV for each funding scenario, the current budget (scenario 1) was also modeled under a restrictive strategy where the entire funding was allocated to the roads in worst condition (similar to the approach currently applied by YHAB). Under this restrictive strategy, heavy maintenance was carried out at an IRI of 8.5, 9.5 or 11 for respectively class II, class III and class IV roads, complemented only by minor (routine) maintenance. This restricted strategy is also presented in Appendix 4.

25. Under the current funding scenario the allocations to intermediate and heavy maintenance only increase slightly during the first 10 years, allowing for the rejuvenation of only around 1% of the highway network each year, much lower than the 8% of heavy maintenance and 5% of intermediate maintenance recommended by MOT. Under the restrictive strategy for this scenario, all roads are left to deteriorate to very poor condition (IRI>7.5) and heavy maintenance is carried out when the road reaches an IRI of 8.5-11 (depending on the road class). In the meantime the road only receives minor maintenance. This strategy is reflective of what YHAB is currently observed to be doing, allocating all its funding for intermediate and heavy maintenance to roads in very poor condition. The HDM-IV model predicts that under this restrictive strategy and the current funding level, the highway network will continue to deteriorate. The percentage of roads in very poor condition (IRI>7.5) will increase from the current 18% to 29% in 2016, after which it will reduce slightly to 25% by 2021. The percentage of roads in good condition (IRI≤3.5) will increase slightly from 19% to 23% in 2016, but will subsequently reduce to 18% by 2021).

26. When the allocation of the maintenance funding under scenario 1 is no longer restricted and HDM-IV is allowed to optimize the strategies to be applied, the situation is slightly better. Under this strategy the focus lies on roads with high traffic volumes, which are improved at the expense of roads with low traffic volumes (which are improved at a later stage). This is done in an effort to reduce operation costs and increase the economic benefits (the improvement of a road with high traffic volumes will result in greater economic benefits than the improvement of a road with low traffic volumes). An analysis of the optimized strategies (see Appendix 4) shows that in 24 of the 38 cases (58% of the network length), intermediate maintenance is carried out when the road is still in good to fair condition (IRI≤5). Where the roads in these cases are already in poor to very poor condition, they are first rehabilitated and subsequently put under a strategy of intermediate maintenance. Only in 9 of the 38 cases (25% of the network length) is the road allowed to deteriorate to a very poor condition (IRI>7.5) before being rehabilitated (this involves mainly roads with low traffic volumes that are expected to deteriorate slowly). Even in these cases, the road is generally rehabilitated at an earlier stage than would be the case under the restricted strategy. Due to the limited budget, however, an additional 5 cases (17% of the network length - mainly roads in very poor condition and with low traffic volumes) go without any intermediate or heavy maintenance at all and receive only minor maintenance as a means of prioritizing the use of the budget for other cases with higher economic benefits. The HDM-IV model predicts that through optimization of the current funding scenario, the percentage of

roads in good condition increases steadily from 19% to 38% in 2021 (mainly roads with higher traffic volumes). This goes at the expense of the percentage of roads in very poor condition that increases from 18% to 34% in 2016 and subsequently reduces slightly to 31% in 2021 (mainly roads with lower traffic volumes). Even under the optimized strategy for funding scenario 1 the road network continues to deteriorate, albeit at a slower rate.

Figure 1: Network Performance Predictions (2011-2021)



IRI = International Roughness Index ; Budget levels only refer to periodic maintenance and rehabilitation

Note: The IRI categories for good, fair, poor and very poor conditions are based on the IRI, and were chosen for their power to efficiently discriminate YHAB's road network. They differ from the ones mentioned in the RRP, the DMF and the maintenance strategy, which rely on the PRC's official Roughness Quality Index categories, and are therefore better for monitoring purposes as they are routinely reported by YHAB.

Source: PPTA Consultant.

27. Under the second funding scenario the annual funding allocation to intermediate and heavy maintenance rapidly increases to CNY 600 million by 2016 and nearly CNY 1 billion by 2021. Under this scenario a greater portion of the network (30 of the 38 cases, 77% of the network length) is kept in good to fair condition (IRI≤5 – in cases with roads in poor or very poor condition only after initial rehabilitation). Only in 5 of the 38 cases (15% of the network length) are roads allowed to deteriorate to poor condition (IRI>7.5) before being rehabilitated (mainly roads with low traffic volumes and asphalt concrete pavement). The limited budget means that in 3 cases (7% of the network length) no intermediate or heavy maintenance is applied and only minor maintenance is carried out (roads in very poor condition with very low traffic volumes). Under this scenario, the HDM-IV model predicts that the highway network would still deteriorate initially from a current 18% in very poor condition to 30% in 2016, but that that percentage would

subsequently decrease to 15% in 2021. The percentage of roads in good condition steadily increase from 19% to 33% in 2016 and 45% in 2021. The improvement is more evenly spread over all traffic categories, although roads with lower traffic volumes are given lower priority and some roads with very low traffic volumes are only improved after 2021. This effectively implies that with such a intermediate increase in funding allocation from the fuel tax, the condition of the highway network could be stabilized and even slightly improved rate.

28. In the third funding scenario, annual funding allocations increase to nearly CNY 1.4 billion by 2016 and reaches CNY 2 billion by 2021. Under this scenario nearly the entire network (37 of the 38 cases, 98% of the network length) is kept in good to fair condition (IRI≤5 – in cases with roads in poor or very poor condition only after initial rehabilitation). Only in 1 of the 38 cases (2% of the network length) are roads allowed to deteriorate to poor condition (IRI>7.5) before being rehabilitated. Under such a funding scenario, the condition of the highway network demonstrates a significant improvement. The HDM-IV model predicts an initial increase in the percentage of roads in very poor condition from the current 18% to 22% in 2016, followed by a significant decrease with the percentage of roads in very poor condition in 2021 expected to be negligible. The percentage of roads in good condition increases strongly from 19% to 56% in 2016 and 64% in 2021. There is an immediate improvement for all traffic categories. This funding scenario would therefore allow the highway network to be significantly improved within a relatively short period.

Table 9: Resulting condition (IRI) under the different scenarios and strategies

Year	Condition	Scenario 1 Restricted	Scenario 1 Optimized	Scenario 2 Optimized	Scenario 2 Optimized
2016	Good (IRI≤3.5)	23%	26%	33%	56%
	Fair (3.5<IRI≤5)	16%	16%	16%	15%
	Poor (5<IRI≤7.5)	32%	24%	21%	7%
	Very Poor (7.5<IRI)	29%	34%	30%	22%
2021	Good (IRI≤3.5)	18%	38%	45%	64%
	Fair (3.5<IRI≤5)	31%	14%	24%	33%
	Poor (5<IRI≤7.5)	26%	17%	16%	3%
	Very Poor (7.5<IRI)	25%	31%	15%	0%

Source: PPTA Team based on HDM-IV analysis.

29. Except for the focus on roads with high traffic volumes under the optimized strategies, there is also a clear shift towards intermediate maintenance of roads in good to fair condition to avoid further deterioration (in some cases after initial rehabilitation). This shift is more evident for the scenarios with increased funding. The result is an increase in road length covered under intermediate and heavy maintenance, even where the optimized strategy under scenario 1 is compared to the restricted strategy. This does not include the road new construction or reconstruction works carried out by other entities than YHAB, assumed to remain at a constant 450 km annually.

Table 10: Length of works (km)

Budget Scenario	2012-2016	2017-2021	2022-2025	2026-2031
Scenario 1 Restricted	1,990	1,840	3,120	4,810
Scenario 1 Optimized	2,280	2,120	3,580	5,530
Scenario 2 Optimized	3,820	5,180	7,120	9,620
Scenario 3 Optimized	8,030	11,180	14,000	17,520

Source: PPTA Team based on HDM-IV analysis.

30. This shift towards intermediate maintenance becomes extra evident when looking at the average length of intermediate and heavy maintenance carried out each year. Where under the current strategy applied by YHAB intermediate maintenance is not carried out at all, under the optimized strategy for the current funding scenario intermediate maintenance makes up 41% of the total average road length receiving maintenance each year. Under scenario 2 this increases to 48% and under scenario 3 to 50%.

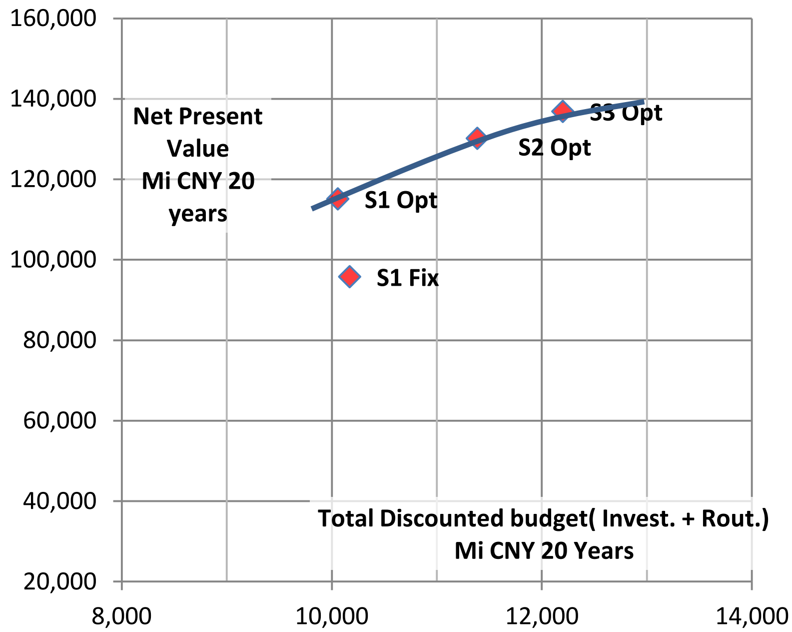
Table 11: Average annual length of intermediate/heavy maintenance (km)

	Scenario 1 Restricted	Scenario 1 Optimized	Scenario 2 Optimized	Scenario 2 Optimized
Heavy maintenance	400	280	410	800
Intermediate maintenance	0	170	360	800

Source: PPTA Team based on HDM-IV analysis.

31. A calculation of the Net Present Value of the entire maintenance expenditures and road reconstruction works for the different funding scenarios and related strategies shows a significant increase in benefits regarding the current funding scenario from the restricted strategy to the optimized strategy. The Net Present Value of the entire program increases by 20% through a simple optimization of the works—about CNY 20 billion additional net benefit over 20 years at no extra cost. Scenarios 2 and 3 also show significant increases in benefits for relatively low cost increases, especially in the case of scenario 2. They correspond to a marginal economic Net Present Value to cost ratio of intermediate and heavy works of 11 for increase maintenance budgets from the scenario 1 levels to the scenario 2, and a ratio of 8 for increasing maintenance budgets from the scenario 2 levels to the scenario 3, demonstrating the very high returns on increased maintenance expenditures.

Figure 2: Reduction of transport costs / total maintenance costs over 20 years
(CNY million)



Source: PPTA Team based on HDM-IV analysis.

32. The conclusion that can be drawn from the HDM-IV analysis is that the current funding levels are inadequate and will result in a gradual deterioration of the highway network. Optimized strategies for the use of existing funds will result in some improvement, but will be insufficient to reverse the deterioration of the network. At the very least the condition of the highway network needs to be stabilized, in which case it would make sense to attract additional funding sources (including loans and multilateral projects) to treat the maintenance backlog and improve the overall road condition.

D. Financial Plan and Maintenance Programming

33. Based on the results of the HDM-IV analysis, it is recommended that YHAB increase its financing for intermediate and heavy maintenance, so that with the two ADB loans, the total financing for intermediate and heavy maintenance reaches CNY500 million annually between 2013 and 2015. It is further recommended that YPDOT will gradually make a larger share of the fuel tax available to YHAB for maintenance, and these additional revenues will be allocated to intermediate and heavy maintenance. It is assumed that by 2017, YHAB will receive 36% of fuel tax resources (compared to 27% in 2011). These funding levels have been set in order that the coverage of intermediate and heavy maintenance reaches an average of 2% of the network in the period 2013-2015, 3% by 2016 and 4% by 2017.[4]

34. The maintenance strategies presented earlier and listed in Appendix 4 are related to the 38 road cases as they have been defined at this moment. That is to say, for each 1 kilometer road section a specific optimized strategy is determined based on its current class, pavement type, condition and traffic level. The strategy to be applied in a specific road section should not be

[4] This financial plan does not consider upgrading works carried out in parallel by YPDOT. In 2011, it is estimated that about 550 km of new road pavement was created through upgrading.

changed, even if its condition or other characteristics change, unless a new strategy study using HDM-IV is carried out.

35. This makes it difficult to use the defined strategies in annual planning of maintenance works. In order to simplify the annual planning of maintenance works, the strategies have been homogenized and simplified, allowing their use in an evolving network where conditions change over time. The result is presented in the two tables below, for asphalt concrete pavement and for simple pavement. These tables also indicate the priorities to be given, with roads with high traffic volumes given higher priority (Priority 1 works to be carried out in the first five years) and roads with low traffic volumes given low priority (Priority 3 works to be carried out after 2021). Priority 2 works for roads with intermediate traffic levels are to be carried out in the second five year-plan, but may also be considered in the first five-year plan if their improvement results in a long continuous section of road in good condition. It must be stressed here that this simplification is at the expense of the optimization of funding allocation and strategy definition. Applying the simplified strategies will therefore result in lower benefits than the optimized strategies.

Table 12: Strategy for asphalt concrete pavement

Traffic	Road Pavement Condition (IRI) IRI≤3.5	3.5<IRI≤5	5<IRI≤7.5	7.5<IRI
ADT <1,000	Heavy when IRI reaches 11	Heavy when IRI reaches 11	Heavy when IRI reaches 11	Heavy when IRI reaches 11
1,000< ADT <2,000	Intermediate when IRI reaches 5	Intermediate when IRI reaches 5	Heavy when IRI reaches 11	Heavy when IRI reaches 11
2,000< ADT <4,000	Intermediate when IRI reaches 5	Intermediate when IRI reaches 5	Heavy when IRI reaches 7.5	Heavy when IRI reaches 9
ADT >4,000	Intermediate when IRI reaches 5	Intermediate when IRI reaches 5	Heavy when IRI reaches 7.5	Heavy when IRI reaches 9

P1 2013-2016 P2 2017-2021 P3 2022-2026

Source: PPTA Consultant Analysis, based on YHAB 2011 Road Condition Survey.

Table 13: Strategy for simple pavement

Traffic	Road Pavement Condition (IRI) IRI≤3.5	3.5<IRI≤5	5<IRI≤7.5	7.5<IRI
ADT <1,000	Intermediate when IRI reaches 5	Intermediate when IRI reaches 5	Minor	Minor
1,000< ADT <2,000	Intermediate when IRI reaches 5	Intermediate when IRI reaches 5	Minor	Minor
2,000< ADT <4,000	Intermediate when IRI reaches 5	Intermediate when IRI reaches 5	Heavy when IRI reaches 7.5	Heavy when IRI reaches 9
ADT >4,000	Intermediate when IRI reaches 5	Intermediate when IRI reaches 5	Heavy when IRI reaches 7.5	Heavy when IRI reaches 9

P1 2013-2016 P2 2017-2021 P3 2022-2026

Source: PPTA Consultant Analysis, based on YHAB 2011 Road Condition Survey.

36. The road length related to each of these cases are indicated in the following tables.

Table 14: Length of asphalt concrete by traffic and condition (km)

	Road Pavement Condition (IRI)				
Traffic	**IRI≤3.5**	**3.5<IRI≤5**	**5<IRI≤7.5**	**7.5<IRI**	**Total**
ADT <1,000	670	1,154	1,406	376	**3,606**
1,000< ADT <2,000	751	940	1,043	318	**3,052**
2,000< ADT <4,000	641	868	586	115	**2,210**
ADT >4,000	738	682	611	151	**2,182**
Total	**2,800**	**3,644**	**3,644**	**959**	**11,050**

Source: PPTA Consultant Analysis, based on YHAB 2011 Road Condition Survey.

Table 15: Length of simple pavement by traffic and condition (km)

	Road Pavement Condition (IRI)				
Traffic	**IRI≤3.5**	**3.5<IRI≤5**	**5<IRI≤7.5**	**7.5<IRI**	**Total**
ADT <1,000	222	636	802	758	**3,606**
1,000< ADT <2,000	152	633	677	892	**3,052**
2,000< ADT <4,000	208	585	848	548	**2,210**
ADT >4,000	311	442	497	393	**2,182**
Total	**893**	**2,296**	**2,824**	**2,590**	**11,050**

Source: PPTA Consultant Analysis, based on YHAB 2011 Road Condition Survey.

37. Overall, priority is given to the maintenance of the roads with traffic above 2,000 ADT. For asphalt pavement, in the next five years, overlays (intermediate maintenance) should be carried out on all roads with traffic above 2,000 before their condition reaches a poor condition (IRI>5), which is associated with the beginning of a quick deterioration of the pavement. Roads with heavy traffic which are already in poor condition should be rehabilitated. Only those roads with traffic between 1,000 and 2,000 ADT in very poor condition should be given priority for rehabilitation. Other roads should only receive minor maintenance in the next five years with more intensive maintenance provided in the next 5-year period.

38. These operational priorities are valid only under given budget assumptions. They optimize the use of the likely budget of YHAB. Technical solutions to be applied should be based on a detailed analysis of the road condition (e.g. cracking, deflection, roughness) and traffic (volumes, growth, overloading), with the objective to provide a 10 year design life to pavements, following the Ministry of Transport's guidance on pavement design. These technical solutions should generally be in line with the proposed maintenance standards listed in Appendix 3, taking into account the road class, the road condition and the traffic volume of the roads concerned.

APPENDIX 1 - MAINTENANCE FUNDING SCENARIOS

Scenario 1 (current funding levels)

Funding (CNY million)	**2009**	**2010**	**2011**	**Expected change**	**Base**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Total fuel tax for Yunnan			6,200	6% annual increase	6,200	6,572	6,966	7,384	7,827	8,297	8,795	9,323	9,882	10,475	11,103	11,769
Fuel tax allocation to YHAB			27%	fixed percentage	27%	27%	27%	27%	27%	27%	27%	27%	27%	27%	27%	27%
Fuel tax	1,280	1,415	1,700	According to percentage of fuel tax allocation	1,700	1,802	1,910	2,025	2,146	2,275	2,411	2,556	2,710	2,872	3,044	3,227
Tolls		156	62	5% annual increase from CNY 20 million base	20	21	22	23	24	26	27	28	30	31	33	34
Overloading		318	370	5% annual increase	370	389	408	428	450	472	496	521	547	574	603	633
YIRNDP (ADB)	-	-	-	CNY 42 million in 2012, 2013, 2014	-	42	42	42	-	-	-	-	-	-	-	-
YSRM (ADB)	-	-	-	CNY 126 million in 2013, 2014, 2015, 2016	-	-	126	126	126	126	-	-	-	-	-	-
other		105	107	2% annual increase	107	109	111	114	116	118	120	123	125	128	130	133
TOTAL		**1,994**	**2,239**		**2,197**	**2,363**	**2,619**	**2,758**	**2,862**	**3,017**	**3,055**	**3,228**	**3,411**	**3,605**	**3,810**	**4,027**
Expenditure (CNY million)	**2009**	**2010**	**2011**	**Expected change**	**Base**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Pensions		620	715	7% increase to 2017, 5% to 2022, then 4%	715	765	819	876	937	1,003	1,073	1,127	1,183	1,242	1,304	1,369
Salaries + bonuses		621	766		766	804	845	887	931	978	1,027	1,078	1,132	1,188	1,248	1,310
Management salaries+bonuses		*92*	*193*	*5% annual increase*	*193*	*203*	*213*	*223*	*235*	*246*	*259*	*272*	*285*	*299*	*314*	*330*
Worker salaries+bonuses		*529*	*573*	*5% annual increase*	*573*	*602*	*632*	*663*	*696*	*731*	*768*	*806*	*847*	*889*	*933*	*980*
Management costs (overhead)		111	191	4% annual increase with CNY 150 million base	150	156	162	169	175	182	190	197	205	213	222	231
Minor (equipment/materials)	218	387	371	5% annual increase	371	390	409	429	451	474	497	522	548	576	604	635
Emergency, flood, greening, equipment	59	62	36	1% annual increase from CNY 50 million base	50	51	51	52	52	53	53	54	54	55	55	56
Intermediate/heavy (equipment/materials)		193	160	All remaining funding	145	197	334	345	315	328	215	250	289	331	377	426
TOTAL	**277**	**1,994**	**2,239**			**2,363**	**2,619**	**2,758**	**2,862**	**3,017**	**3,055**	**3,228**	**3,411**	**3,605**	**3,810**	**4,027**
New pavement (CNY million)	**2009**	**2010**	**2011**	**Expected change**	**Base**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
YHAB new pavement	-	193	160	As above	145	197	334	345	315	328	215	250	289	331	377	426
Other new pavement				Fixed annual amount	555	555	555	555	555	555	555	555	555	555	555	555
TOTAL					**700**	**752**	**889**	**900**	**870**	**883**	**770**	**805**	**844**	**886**	**932**	**981**
TOTAL - inflation corrected				Only YHAB investment corrected		**746**	**870**	**871**	**835**	**838**	**735**	**759**	**783**	**809**	**835**	**863**

Scenario 2 (slight increase in fuel tax allocation)

Funding (CNY million)	**2009**	**2010**	**2011**	**Expected change**	**Base**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Total fuel tax for Yunnan			6,200	6% annual increase	6,200	6,572	6,966	7,384	7,827	8,297	8,795	9,323	9,882	10,475	11,103	11,769
Fuel tax allocation to YHAB			27%	Increase from 27% to 32% FT allocation by 2017	27%	27%	28%	29%	30%	31%	32%	32%	32%	32%	32%	32%
Fuel tax	1,280	1,415	1,700	According to percentage of fuel tax allocation	1,700	1,802	1,951	2,141	2,348	2,572	2,814	2,983	3,162	3,352	3,553	3,766
Tolls		156	62	5% annual increase from CNY 20 million base	20	21	22	23	24	26	27	28	30	31	33	34
Overloading		318	370	5% annual increase	370	389	408	428	450	472	496	521	547	574	603	633
YIRNDP (ADB)	-	-	-	CNY 42 million in 2012, 2013, 2014	-	42	42	42	-	-	-	-	-	-	-	-
					-	-	-	-	-	-	-	-	-	-	-	-
YSRM (ADB)	-	-	-	CNY 126 million in 2013, 2014, 2015, 2016	-	-	126	126	126	126	-	-	-	-	-	-
					-	-	-	-	-	-	-	-	-	-	-	-
other		105	107	2% annual increase	107	109	111	114	116	118	120	123	125	128	130	133
TOTAL		**1,994**	**2,239**		**2,197**	**2,363**	**2,660**	**2,874**	**3,064**	**3,314**	**3,457**	**3,655**	**3,864**	**4,085**	**4,319**	**4,566**
Expenditure (CNY million)	**2009**	**2010**	**2011**	**Expected change**	**Base**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Pensions		620	715	7% increase to 2017, 5% to 2022, then 4%	715	765	819	876	937	1,003	1,073	1,127	1,183	1,242	1,304	1,369
Salaries + bonuses		621	766		766	804	845	887	931	978	1,027	1,078	1,132	1,188	1,248	1,310
Management salaries+bonuses		*92*	*193*	*5% annual increase*	*193*	*203*	*213*	*223*	*235*	*246*	*259*	*272*	*285*	*299*	*314*	*330*
Worker salaries+bonuses		*529*	*573*	*5% annual increase*	*573*	*602*	*632*	*663*	*696*	*731*	*768*	*806*	*847*	*889*	*933*	*980*
Management costs (overhead)		111	191	4% annual increase with CNY 150 million base	150	156	162	169	175	182	190	197	205	213	222	231
Minor (equipment/materials)	218	387	371	5% annual increase	371	390	409	429	451	474	497	522	548	576	604	635
Emergency, flood, greening, equipment	59	62	36	1% annual increase from CNY 50 million base	50	51	51	52	52	53	53	54	54	55	55	56
Intermediate/heavy (equipment/materials)		193	160	All remaining funding	145	197	374	462	517	625	618	677	741	811	885	965
TOTAL	**277**	**1,994**	**2,239**			**2,363**	**2,660**	**2,874**	**3,064**	**3,314**	**3,457**	**3,655**	**3,864**	**4,085**	**4,319**	**4,566**
New pavement (CNY million)	**2009**	**2010**	**2011**	**Expected change**	**Base**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
YHAB new pavement	-	193	160	As above	145	197	374	462	517	625	618	677	741	811	885	965
Other new pavement				Fixed annual amount	555	555	555	555	555	555	555	555	555	555	555	555
TOTAL					**700**	**752**	**929**	**1,017**	**1,072**	**1,180**	**1,173**	**1,232**	**1,296**	**1,366**	**1,440**	**1,520**
TOTAL - inflation corrected				Only YHAB investment corrected		**746**	**908**	**978**	**1,015**	**1,094**	**1,072**	**1,106**	**1,140**	**1,176**	**1,214**	**1,252**

Scenario 3 (Significant increase in fuel tax allocation + improved implementation efficiency)

Funding (CNY million)	**2009**	**2010**	**2011**	**Expected change**	**Base**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Total fuel tax for Yunnan			6,200	6% annual increase	6,200	6,572	6,966	7,384	7,827	8,297	8,795	9,323	9,882	10,475	11,103	11,769
Fuel tax allocation to YHAB			27%	Increase from 27% to 40% FT allocation by 2017	27%	27%	31%	34%	37%	39%	40%	40%	40%	40%	40%	40%
Fuel tax	1,280	1,415	1,700	According to percentage of fuel tax allocation	1,700	1,802	2,160	2,511	2,896	3,236	3,518	3,729	3,953	4,190	4,441	4,708
Tolls		156	62	5% annual increase from CNY 20 million base	20	21	22	23	24	26	27	28	30	31	33	34
Overloading		318	370	5% annual increase	370	389	408	428	450	472	496	521	547	574	603	633
YIRNDP (ADB)	-	-	-	CNY 42 million in 2012, 2013, 2014	-	42	42	42	-	-	-	-	-	-	-	-
YSRM (ADB)	-	-	-	CNY 126 million in 2013, 2014, 2015, 2016	-	-	126	126	126	126	-	-	-	-	-	-
other		105	107	2% annual increase	107	109	111	114	116	118	120	123	125	128	130	133
TOTAL		**1,994**	**2,239**		**2,197**	**2,363**	**2,869**	**3,244**	**3,612**	**3,978**	**4,161**	**4,401**	**4,654**	**4,923**	**5,207**	**5,508**
Expenditure (CNY million)	**2009**	**2010**	**2011**	**Expected change**	**Base**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Pensions		620	715	7% increase to 2017, 5% to 2022, then 4%	715	765	819	876	937	1,003	1,073	1,127	1,183	1,242	1,304	1,369
Salaries + bonuses		621	766		766	804	802	842	885	929	975	1,024	1,075	1,129	1,185	1,245
Management salaries+bonuses		*92*	*193*	*5% lower than base scenario*	*193*	*203*	*202*	*212*	*223*	*234*	*246*	*258*	*271*	*284*	*299*	*314*
Worker salaries+bonuses		*529*	*573*	*5% lower than base scenario*	*573*	*602*	*600*	*630*	*662*	*695*	*729*	*766*	*804*	*844*	*887*	*931*
Management costs (overhead)		111	191	5% lower than base scenario	150	156	154	160	167	173	180	188	195	203	211	219
Minor (equipment/materials)	218	387	371	5% lower than base scenario	371	390	389	408	428	450	472	496	521	547	574	603
Emergency, flood, greening, equipment	59	62	36	1% annual increase from CNY 50 million base	50	51	51	52	52	53	53	54	54	55	55	56
Intermediate/heavy (equipment/materials)		193	160	All remaining funding	145	197	654	906	1,143	1,370	1,407	1,513	1,626	1,747	1,877	2,016
TOTAL	**277**	**1,994**	**2,239**			**2,363**	**2,869**	**3,244**	**3,612**	**3,978**	**4,161**	**4,401**	**4,654**	**4,923**	**5,207**	**5,508**
New pavement (CNY million)	**2009**	**2010**	**2011**	**Expected change**	**Base**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
YHAB new pavement	-	193	160	As above	145	197	654	906	1,143	1,370	1,407	1,513	1,626	1,747	1,877	2,016
Other new pavement				Fixed annual amount	555	555	555	555	555	555	555	555	555	555	555	555
TOTAL					**700**	**752**	**1,209**	**1,461**	**1,698**	**1,925**	**1,962**	**2,068**	**2,181**	**2,302**	**2,432**	**2,571**
TOTAL - inflation corrected				Only YHAB investment corrected		**746**	**1,172**	**1,384**	**1,571**	**1,737**	**1,733**	**1,785**	**1,839**	**1,894**	**1,952**	**2,011**

APPENDIX 2 - MAINTENANCE STANDARDS

Road class	Code	Technique	Annual limit	Cost
MINOR MAINTENANCE STANDARDS				
Class II	ROUTINE C2	Pot holing Crack Patching Raveling	1 month - 100% 100% - 300m2/year 100% - 300m2/year	125 CNY/m^2
Class III, IV	ROUTINE C3	Pot holing Crack Patching Raveling	1 month - 100% 50% - 200m2/year 50% - 200m2/year	125 CNY/m^2
CURRENT HEAVY MAINTENANCE STANDARDS				
Road class	**Code**	**Technique**	**Thresholds**	**Cost**
Class II	REHAB C2 IRI 8.5	AC 8 cm CTG 20 cm	IRI 8.5	160 CNY/m^2
Class III	REHAB C3 IRI 9.5	AC 6 cm CTG 17 cm	IRI 9.5	125 CNY/m^2
Class IV	REHAB C4 IRI 11	AC 6 cm CGT 17 cm	IRI 11	125 CNY/m^2
PROPOSED INTERMEDIATE MAINTENANCE STANDARDS				
Road class	**Code**	**Tech.**	**Thresholds**	**Cost**
Class II	PREV C2 IRI 3.5	AC 4 cm	IRI =3.5 OR 15% all structural cracks	40 CNY/m^2
Class II	PREV C2 IRI 5	AC 4 cm	IRI =5 OR 30% all structural cracks	40 CNY/m^2
Class II	REINF C2 IRI 5	AC 8 cm	IRI =5 OR 30 % all structural cracks	65 CNY/m^2
Class III,IV	PREV C3 IRI 3.5	AC 4 cm	IRI =5 OR 25% all structural cracks	40 CNY/m^2
Class III,IV	PREV C3 IRI 5	AC 5 cm	IRI =5 OR 50 % all structural cracks	40 CNY/m^2
Class III,IV	REINF C3 R 5	AC 6 cm	IRI =5 OR 50 % all structural cracks	55 CNY/m^2
PROPOSED HEAVY MAINTENANCE STANDARDS				
Road class	**Code**	**Technique**	**Thresholds**	**Cost**
Class II	REHAB C2 IRI 5	AC 8 cm CTG 20 cm	IRI =5 OR 25% all structural cracks	185 CNY/m^2
Class II	REHAB C2 IRI 7.5	AC 8 cm CTG 30 cm	IRI =7.5 OR 50 % all structural cracks	185 CNY/m^2
Class II	REHAB C2 IRI 10	AC 8 cm CTG 30 cm	IRI =7.5 OR 50 % all structural cracks	185 CNY/m^2
Class III,IV	REHAB C3 IRI 5	AC 6 cm CTG 17 cm	IRI =5 OR 75% all structural cracks	125 CNY/m^2
Class III,IV	REHAB C3 IRI 7.5	AC 6 cm CTG 17 cm	IRI =7.5 OR 75% all structural cracks	125 CNY/m^2
Class III,IV	REHAB C3 IRI 7.5 T4	AC 6 cm CTG 25 cm	IRI =7.5 OR 75% all structural cracks	150 CNY/m^2
Class III,IV	REHAB C3 IRI 10	AC 6 cm CTG 17 cm	IRI =10 or 75% all structural cracks	125 CNY/m^2
Class III,IV	REHAB C3 IRI 10 T4	AC 8 cm CTG 20 cm	IRI =10 or 75% all structural cracks	160 CNY/m^2
Class III,IV	REHAB C3 IRI 10 T4R4	AC 8 cm CTG 30 cm	IRI =10 or 75% all structural cracks	190 CNY/m^2

Source: PPTA Team

APPENDIX 3 - MAINTENANCE STRATEGIES

Road class	Strategies		
	Initial investment	Associated maintenance	Code
C2	REHAB C2 IRI 8.5*	Minor	C2-0
	PREV C2 IRI 3.5	Minor	C2-1
	PREV C2 IRI 5	Minor	C2-2
	REINF C2 IRI 5	Minor	C2-3
	REHAB C2 IRI 7.5	Minor	C2-4
	REHAB C2 IRI 5	PREV C2 IRI 3.5	C2-5
	REHAB C2 IRI 5	REINF C2 IRI 5	C2-6
	REHAB C2 IRI 7.5	PREV C2 IRI 3.5	C2-7
	REHAB C2 IRI 7.5	REINF C2 IRI 5	C2-8
	REHAB C2 IRI 9	PREV C2 IRI 5	C2-9
	REHAB C2 IRI 10	PREV C2 IRI 5	C2-10
C3	REHAB C3 IRI 9.5*	Minor	C3-0
	REINF C3 IRI 5	Minor	C3-3
	REHAB C3 IRI 7.5	Minor	C3-4
	REHAB C3 IRI 5	PREV C3 IRI 5	C3-6
	REHAB C3 IRI 7.5	PREV C3 IRI 3.5	C3-7
	REHAB C3 IRI 7.5	PREV C3 IRI 5	C3-8
	REHAB C3 IRI 10	PREV C3 IRI 5	C3-9
	REHAB C3 IRI 10	REINF C3 IRI 7.5	C3-10
	REHAB C3 IRI 7.5 T4	PREV C3 IRI 5	C3-11
	REHAB C3 IRI 10 T4R4	PREV C3 IRI 5	C3-12
C4	REHAB C3 IRI 11*	Minor	C4-0
	REINF C3 IRI 5	Minor	C4-3
	REHAB C3 IRI 7.5	Minor	C4-4
	REHAB C3 IRI 5	PREV C3 IRI 5	C4-6
	REHAB C3 IRI 7.5	PREV C3 IRI 5	C4-8
	REHAB C3 IRI 10	PREV C3 IRI 5	C4-9
	REHAB C3 IRI 12	PREV C3 IRI 5	C4-10
	REHAB C3 IRI 12 T4	PREV C3 IRI 5	C4-11

* = Current strategy
Source: PPTA team

APPENDIX 4 – OPTIMIZED MAINTENANCE STRATEGIES

Case	Length (km)	Scenario 1 Restricted	Scenario 1 Optimized	Scenario 2 Optimized	Scenario 3 Optimized
T1C2R1P1	394	REHAB C2 IRI 8.5*	C2-3 REINF C2 IRI 5	C2-3 REINF C2 IRI 5	C2-3 REINF C2 IRI 5
T1C4R1P1	276	REHAB C3 IRI 11*	C4-4 REHAB C3 IRI 7.5	C4-3 REINF C3 IRI 5	C4-3 REINF C3 IRI 5
T1C4R1P2	222	REHAB C3 IRI 11*	C4-3 REINF C3 IRI 5	C4-3 REINF C3 IRI 5	C4-3 REINF C3 IRI 5
T1C4R2P1	1,154	REHAB C3 IRI 11*	C4-8 REHAB C3 IRI 7.5+PREV C3 IRI 5	C4-8 REHAB C3 IRI 7.5+PREV C3 IRI 5	C4-3 REINF C3 IRI 5
T1C4R2P2	636	REHAB C3 IRI 11*	C4-8 REHAB C3 IRI 7.5+PREV C3 IRI 5	C4-8 REHAB C3 IRI 7.5+PREV C3 IRI 5	C4-8 REHAB C3 IRI 7.5+PREV C3 IRI 5
T1C4R3P1	1,406	REHAB C3 IRI 11*	C4-0 REHAB C3 IRI 11*	C4-0 REHAB C3 IRI 11*	C4-10 REHAB IRI 12+PREV C3 IRI 5
T1C4R3P2	802	REHAB C3 IRI 11*	C4-10 REHAB C3 IRI 12+PREV C3 IRI 5	C4-9 REHAB C3 IRI 10+PREV C3 IRI 5	C4-9 REHAB C3 IRI 10+PREV C3 IRI 5
T1C4R4P1	376	REHAB C3 IRI 11*	Minor only	Minor only	C4-9 REHAB C3 IRI 10+PREV C3 IRI 5
T1C4R4P2	758	REHAB C3 IRI 11*	Minor only	Minor only	C4-9 REHAB C3 IRI 10+PREV C3 IRI 5
T2C2R2P1	409	REHAB C2 IRI 8.5*	C2-0 REHAB C2 IRI 8.5*	C2-4 REHAB C2 IRI 7.5	C2-2 PREV C2 IRI 5
T2C2R3P1	393	REHAB C2 IRI 8.5*	Minor only	C2-7 REHAB C2 IRI 7.5+PREV C2 IRI 3.5	C2-7 REHAB C2 IRI 7.5+PREV C2 IRI 3.5
T2C3R1P1	751	REHAB C3 IRI 9.5*	C3-4 REHAB C3 IRI 7.5	C3-3 REINF C3 IRI 5	C3-3 REINF C3 IRI 5
T2C3R1P2	152	REHAB C3 IRI 9.5*	C3-3 REINF C3 IRI 5	C3-3 REINF C3 IRI 5	C3-3 REINF C3 IRI 5
T2C4R2P1	531	REHAB C3 IRI 11*	C4-4 REHAB C3 IRI 7.5	C4-4 REHAB C3 IRI 7.5	C4-3 REINF C3 IRI 5
T2C4R2P2	633	REHAB C3 IRI 11*	C4-9 REHAB C3 IRI 10+PREV C3 IRI 5	C4-3 REINF C3 IRI 5	C4-3 REINF C3 IRI 5
T2C4R3P1	650	REHAB C3 IRI 11*	C4-9 REHAB C3 IRI 10+PREV C3 IRI 5	C4-9 REHAB C3 IRI 10+PREV C3 IRI 5	C4-9 REHAB C3 IRI 10+PREV C3 IRI 5
T2C4R3P2	677	REHAB C3 IRI 11*	C4-0 REHAB C3 IRI 11*	C4-9 REHAB C3 IRI 10+PREV C3 IRI 5	C4-9 REHAB C3 IRI 10+PREV C3 IRI 5
T2C4R4P1	318	REHAB C3 IRI 11*	C4-9 REHAB C3 IRI 10+PREV C3 IRI 5	Minor only	C4-9 REHAB C3 IRI 10+PREV C3 IRI 5
T2C4R4P2	892	REHAB C3 IRI 11*	Minor only	C4-9 REHAB C3 IRI 10+PREV C3 IRI 5	C4-9 REHAB C3 IRI 10+PREV C3 IRI 5
T3C2R1P1	641	REHAB C2 IRI 8.5*	C2-1 PREV C2 IRI 3.5	C2-1 PREV C2 IRI 3.5	C2-1 PREV C2 IRI 3.5
T3C2R2P1	381	REHAB C2 IRI 8.5*	C2-0 REHAB C2 IRI 8.5*	C2-4 REHAB C2 IRI 7.5	C2-2 PREV C2 IRI 5
T3C2R3P1	310	REHAB C2 IRI 8.5*	C2-0 REHAB C2 IRI 8.5*	C2-0 REHAB C2 IRI 8.5*	C2-0 REHAB C2 IRI 8.5*
T3C3R1P2	208	REHAB C3 IRI 9.5*	C3-4 REHAB C3 IRI 7.5	C3-3 REINF C3 IRI 5	C3-3 REINF C3 IRI 5
T3C3R2P2	585	REHAB C3 IRI 9.5*	C3-3 REINF C3 IRI 5	C3-3 REINF C3 IRI 5	C3-3 REINF C3 IRI 5
T3C3R3P2	848	REHAB C3 IRI 9.5*	Minor only	C3-8 REHAB C3 IRI 7.5+PREV C3 IRI 5	C3-8 REHAB C3 IRI 7.5+PREV C3 IRI 5
T3C3R4P1	115	REHAB C3 IRI 9.5*	C3-8 REHAB C3 IRI 7.5+PREV C3 IRI 5	C3-9 REHAB C3 IRI 10+PREV C3 IRI 5	C3-8 REHAB C3 IRI 7.5+PREV C3 IRI 5
T3C3R4P2	548	REHAB C3 IRI 9.5*	C3-8 REHAB C3 IRI 7.5+PREV C3 IRI 5	C3-8 REHAB C3 IRI 7.5+ PREV C3 IRI 5	C3-8 REHAB C3 IRI 7.5+PREV C3 IRI 5
T3C4R2P1	487	REHAB C3 IRI 11*	C4-3 REINF C3 IRI 5	C4-3 REINF C3 IRI 5	C4-3 REINF C3 IRI 5
T3C4R3P1	276	REHAB C3 IRI 11*	C4-8 REHAB C3 IRI 7.5+PREV C3 IRI 5	C4-10 REHAB C3 IRI 10+PREV C3 IRI 5	C4-8 REHAB C3 IRI 7.5+PREV C3 IRI 5
T4C2R1P1	738	REHAB C2 IRI 8.5*	C2-1 PREV C2 IRI 3.5	C2-1 PREV C2 IRI 3.5	C2-1 PREV C2 IRI 3.5
T4C2R2P1	682	REHAB C2 IRI 8.5*	C2-2 PREV C2 IRI 5	C2-2 PREV C2 IRI 5	C2-2 PREV C2 IRI 5
T4C2R3P1	357	REHAB C2 IRI 8.5*	C2-9 REHAB C2 IRI 9+PREV C2 IRI 5	C2-9 REHAB C2 IRI 9+PREV C2 IRI 5	C2-9 REHAB C2 IRI 9+PREV C2 IRI 5
T4C2R4P1	151	REHAB C2 IRI 8.5*	C2-9 REHAB C2 IRI 9+PREV C2 IRI 5	C2-9 REHAB C2 IRI 9+PREV C2 IRI 5	C2-9 REHAB C2 IRI 9+PREV C2 IRI 5
T4C3R1P2	311	REHAB C3 IRI 9.5*	C3-3 REINF C3 IRI 5	C3-3 REINF C3 IRI 5	C3-3 REINF C3 IRI 5
T4C3R3P1	254	REHAB C3 IRI 9.5*	C3-11 REHAB C3 IRI 7.5 T4+PREV C3 IRI 5	C3-11 REHAB C3 IRI 7.5 T4+PREV C3 IRI 5	C3-11 REHAB C3 IRI 7.5 T4+PREV C3 IRI 5
T4C3R3P2	497	REHAB C3 IRI 9.5*	C3-11 REHAB C3 IRI 7.5 T4+PREV C3 IRI 5	C3-11 REHAB C3 IRI 7.5 T4+PREV C3 IRI 5	C3-11 REHAB C3 IRI 7.5 T4+PREV C3 IRI 5
T4C3R4P2	393	REHAB C3 IRI 9.5*	C3-12 REHAB C3 T4R4 IRI 10+PREV C3 IRI 5	C3-12 REHAB C3 IRI 10 T4R4+PREV C3 IRI 5	C3-12 REHAB C3 IRI 10 T4R4+PREV C3 IRI 5
T4C4R2P2	442	REHAB C3 IRI 11*	C4-8 REHAB C3 IRI 7.5+PREV C3 IRI 5	C4-9 REHAB C3 IRI 10+PREV C3 IRI 5	C3-12 REHAB C3 IRI 10 T4R4+PREV C3 IRI 5

Road kept in good-fair condition (IRI≤5) — Road allowed to deteriorate to very poor condition (IRI>7.5) — Road receives no intermediate/heavy maintenance

* = Current Strategy
Source: PPTA Team