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APPENDIX

APPENDIX A

Table A 1 Calculation of Equivalence Factors[1] for Heavy Vehicles

2 - axle				3 - axle				
Weight, tonnes	0.35wt.	0.65wt.	Eq.factor	Weight, tonnes	0.20wt.	0.41wt.	0.39wt.	Eq.factor
5.5	1.925	3.575	0.025	7.2	1.44	2.952	2.808	0.019
7.0	2.450	4.550	0.075	12.0	2.40	4.920	4.680	0.185
7.2	2.520	4.680	0.085	13.0	2.60	5.330	5.070	0.265
7.7	2.695	5.005	0.115	14.0	2.80	5.740	5.460	0.369
7.8	2.730	5.070	0.122	15.0	3.00	6.150	5.850	0.504
7.9	2.765	5.135	0.129	16.0	3.20	6.560	6.240	0.673
8.0	2.800	5.200	0.137	16.2	3.24	6.642	6.318	0.712
8.6	3.010	5.590	0.189	16.5	3.30	6.765	6.435	0.773
9.0	3.150	5.850	0.232	16.7	3.34	6.847	6.513	0.816
9.4	3.290	6.110	0.283	17.0	3.40	6.970	6.630	0.885
9.5	3.325	6.175	0.296	17.6	3.52	7.216	6.864	1.034
9.6	3.360	6.240	0.311	17.8	3.56	7.298	6.942	1.088
9.7	3.395	6.305	0.325	18.0	3.60	7.380	7.020	1.144
9.8	3.430	6.370	0.341	18.2	3.64	7.462	7.098	1.202
10.0	3.500	6.500	0.373	18.4	3.68	7.544	7.176	1.263
10.3	3.605	6.695	0.426	18.6	3.72	7.626	7.254	1.326
10.5	3.675	6.825	0.465	19.0	3.80	7.790	7.410	1.459
11.0	3.850	7.150	0.573	19.2	3.84	7.872	7.488	1.530
11.2	3.920	7.280	0.621	19.5	3.90	7.995	7.605	1.642
11.3	3.955	7.345	0.647	19.8	3.96	8.118	7.722	1.757
11.4	3.990	7.410	0.673	20.0	4.00	8.200	7.800	1.838
11.5	4.025	7.475	0.700	20.2	4.04	8.282	7.878	1.922
11.7	4.095	7.605	0.756	20.3	4.06	8.323	7.917	1.965
12.0	4.200	7.800	0.848	20.5	4.10	8.405	7.995	2.054
				20.8	4.16	8.528	8.112	2.193

[1] Equivalence factor $= \sum_i \left(\frac{L_i}{8200}\right)^{4.5}$

where L_i = load on axle i, kg

Table A 2 Observations and Summed Equivalence Factors and Average Payload, Heavy Vehicles Southbound on Saraburi - Ban Phu Kae Segment

2 - axle				3 - axle			
Weight, tonnes	Eq.factor	Frequency	Total Eq.factor	Weight, tonnes	Eq.factor	Frequency	Total Eq.factor
7.0	0.075	2	0.150	15.0	0.504	1	0.504
8.0	0.137	1	0.137	16.0	0.673	3	2.019
9.6	0.311	1	0.311	16.7	0.816	1	0.816
9.8	0.341	1	0.341	17.0	0.885	5	4.425
10.0	0.373	7	2.611	17.6	1.034	4	4.136
10.3	0.426	1	0.426	17.8	1.088	9	9.792
10.5	0.465	4	1.860	18.0	1.144	68	77.792
11.0	0.573	3	1.719	18.2	1.202	3	3.606
11.2	0.621	1	0.621	18.4	1.263	1	1.263
11.3	0.647	1	0.647	18.6	1.326	1	1.326
11.4	0.673	2	1.346	19.0	1.459	2	2.918
11.5	0.700	1	0.700	19.2	1.530	1	1.530
12.0	0.848	1	0.848	19.5	1.642	6	9.852
				19.8	1.757	3	5.271
Total		26	11.717	20.0	1.838	21	38.598
				20.2	1.922	1	1.922
				20.3	1.965	1	1.965
				20.5	2.054	5	10.270
				20.8	2.193	1	2.193
				Total		137	180.198

Av. equivalence factor $= \frac{11.717}{26} = 0.45$

Av. unladen weight = 5.5 tonnes

Av. payload $= \frac{265.5}{26} - 5.5 = 4.7$ tonnes

Av. equivalence factor $= \frac{180.198}{137} = 1.315$

Av. unladen weight = 7.2 tonnes

Av. payload $= \frac{2528.3}{137} - 7.2 = 11.3$ tonnes

Table A 3 Observations and Summed Equivalence Factors and Average Payload, Heavy Vehicles Northbound on Saraburi - Ban Phu Kae Segment

2 - axle				3 - axle			
Weight, tonnes	Eq.factor	Frequency	Total Eq.factor	Weight, tonnes	Eq.factor	Frequency	Total Eq.factor
5.5	0.025	8	0.200	7.2	0.019	110	2.090
7.2	0.085	1	0.085	12.0	0.185	1	0.185
7.7	0.115	1	0.115	13.0	0.265	1	0.265
7.8	0.122	1	0.122	14.0	0.369	1	0.369
7.9	0.129	1	0.129	15.0	0.504	2	1.008
8.0	0.137	2	0.274	16.2	0.712	1	0.712
8.6	0.189	1	0.189	16.5	0.773	2	1.546
9.4	0.283	1	0.283	17.0	0.885	6	5.310
9.5	0.296	1	0.296	17.6	1.034	5	5.170
9.7	0.325	1	0.325	17.8	1.088	1	1.088
9.8	0.341	1	0.341	18.0	1.144	5	5.720
10.0	0.373	4	1.492	19.0	1.459	1	1.459
10.5	0.465	1	0.465	20.0	1.838	1	1.838
11.0	0.573	1	0.573	Total		137	26.760
11.7	0.756	1	0.756				
Total		26	5.645				

Av. equivalence factor $= \frac{5.645}{26} = 0.217$

Av. payload $= \frac{210.8}{26} - 5.5 = 2.6$ tonnes

Av. equivalence factor $= \frac{26.760}{137} = 0.195$

Av. payload $= \frac{1247}{137} = 7.2 = 1.9$ tonnes

Table A 4 Observations and Summed Equivalence Factors and Average Payload, Heavy Vehicles Southbound on Ban Phu Kae - Lamnarai Segment

2 -axle				3 - axle			
Weight, tonnes	Eq.factor	Frequency	Total Eq.factor	Weight, tonnes	Eq.factor	Frequency	Total Eq.factor
7.0	0.075	1	0.075	16.0	0.673	2	1.346
9.6	0.311	1	0.311	17.0	0.885	3	2.655
9.8	0.341	1	0.341	17.6	1.034	1	1.034
10.0	0.373	6	2.238	17.8	1.088	5	5.440
10.5	0.465	1	0.465	18.0	1.144	32	36.608
11.0	0.573	2	1.146	18.4	1.263	1	1.263
11.5	0.700	1	0.700	18.6	1.326	1	1.326
Total		13	5.276	19.0	1.459	1	1.459
				19.2	1.530	1	1.530
				19.5	1.642	3	4.926
				19.8	1.757	2	3.514
				20.0	1.838	5	9.190
				20.2	1.922	1	1.922
				20.3	1.965	1	1.965
				20.5	2.054	3	6.162
				Total		62	78.418

2 -axle	3 - axle
Av. equivalence factor $= \frac{5.276}{13} = 0.406$	Av. equivalence factor $= \frac{78.418}{62} = 1.265$
Av. payload $= \frac{130.4}{13} - 5.5 = 4.5$ tonnes	Av. payload $= \frac{1140.9}{62} - 7.2 = 11.2$ tonnes

Table A 5 Observations and Summed Equivalence Factors and Average Payload,

Heavy Vehicles Northbound on Ban Phu Kae - Lamnarai Segment

2 - axle				3 - axle			
Weight, tonnes	Eq.factor	Frequency	Total Eq.factor	Weight, tonnes	Eq.factor	Frequency	Total Eq.factor
5.5	0.025	11	0.275	7.2	0.019	52	0.988
10.0	0.373	1	0.373	12.0	0.185	1	0.185
11.7	0.756	1	0.756	15.0	0.504	2	1.008
				16.2	0.712	1	0.712
Total		13	1.404	16.5	0.773	2	1.546
				17.0	0.885	2	1.770
				18.0	1.144	1	1.144
				20.0	1.838	1	1.838
				Total		62	9.191

Av. equivalence factor $= \frac{1.404}{13} = 0.108$ Av. equivalence factor $= \frac{9.191}{62} = 0.148$

Av. payload $= \frac{82.2}{13} - 5.5 = 0.8$ tonnes Av. payload $= \frac{537.6}{62} - 7.2 = 1.5$ tonnes

Heavy buses unladen weight = 7.0 tonnes, av. occupancy = 23 persons

1 seat say = 80 kg, 23 seats = 1.84 tonnes, say 2 tonnes

Payload = 2.0 tonnes

Eq. factor = 0.232 for each direction.

Table A 6 Calculations of Exponential Regression Curve for Traffic Volume: Saraburi - Ban Phu Khae Station 121 + 000.

year	x	(ADT) y	x^2	logy	xlogy
1969	1	4,129	1	3.61584	3.61584
1970	2	5,164	4	3.71299	7.42597
1971	3	5,153	9	3.71206	11.13618
1972	4	5,239	16	3.71925	14.87699
1973	5	5,872	25	3.76879	18.84393
1974	6	5,398	36	3.73223	22.39340
Total	21	30,955	91	22.26116	78.29231

$\bar{x} = 3.5$, $\overline{\log y} = 3.71019$

Exponential Regression $b = \frac{n\Sigma x \log y - (\Sigma x)(\Sigma \log y)}{n\Sigma x^2 - (\Sigma x)^2}$

$= \frac{6(78.29231) - (21)(22.26116)}{6(91) - (21)^2} = 0.021614$

$a = \overline{\log y} - b\bar{x}$	$c = 10^a$	$d = 10^b$
$= 3.71019 - 0.2161\,(3.5)$	$= 10^{3.63454}$	$= 10^{0.021614}$
$= 3.63454$	$= 4310.6$	$= 1.05103$

$y = cd^x$; $y = (4310.6)\,(1.051)^x$

Table A 7 1970 ADT from Regression, and Percentage Distribution of type of vehicles obtained from Thai Highway Department : Saraburi - Ban Phu Kae Segment.

Vehicle Type	Percentage at total vehicles	1970 ADT
Cars and taxis	33.4	1590
Light trucks	9.4	448
Light buses	7.7	367
Heavy buses	9.4	448
2 - axle trucks	14.7	700
3 - axle trucks	25.4	1209
Total	100	4762

Table A 8 Calculations of Exponential Regression Curve for Traffic Volumes

Ban Phu Khae - Lamnarai Station 20 + 900

year	x	ADT y	x^2	logy	xlogy
1972	1	1229	1	3.1136	3.1136
1973	2	1393	4	3.1440	6.2879
1974	3	1224	9	3.0878	9.2633
1975	4	1473	16	3.1682	12.6728
Total	10	5309	30	12.5135	31.3377

$\bar{x} = 2.5$, $\overline{\log y} = 3.1284$

Exponential Regression $b = \dfrac{n\Sigma x \log y - (\Sigma x)(\Sigma \log y)}{n\Sigma x^2 - (\Sigma x)^2}$

$= \dfrac{4(31.3377) - 10(12.5135)}{4(30) - (10)^2} = 0.01079$

$a = \overline{\log y} - b\bar{x}$	$c = 10^a$	$d = 10^b$
$= 3.1284 - (0.01079)(2.5)$	$= 10^{3.10143}$	$= 10^{0.01072}$
$= 3.10143$	$= 1263$	$= 1.025$

$y = cd^x$, $y = (1263)(1.025)^x$

Table A 9 1970 ADT from Regression, and Percentage Distribution of type of vehicles obtained from Thai Highway Department :

Ban Phu Kae - Lamnarai Segment.

Vehicle Type	Percentage at total vehicles	1970 ADT
Cars and taxis	22.2	273
Light trucks	13.3	164
Light buses	9.6	118
Heavy buses	8.7	107
2 - axle trucks	16.2	200
3 - axle trucks	30.0	370
Total	100.0	1232

APPENDIX B

Table B 1

The Thai Highway Department classification of maintenance cost accounts is set forth in the following listing.

1) Administration

- Clerical administration
- Cost of services, office expenses, etc.
- Routine field inspection
- Unkeep of District workshops

2) Land and buildings

- Maintenance of land and buildings

3) Routine surface operations

- Heavy grading
- Light grading
- Soil aggregate surface patching
- Skin patching of paved roads
- Minor repair of asphalt pavement
- Concrete patching
- Concrete joint sealing
- Roadway clearing

4) Shoulders, side road approaches, and median strips

- Shoulder grass cutting
- Shoulder patching
- Shoulder light grading

5) Drainage

- Drainage cleaning
- Waterway restoration
- Culvert cleaning and repairing

6) Roadside maintenance

- Side slope repairing
- Roadside grass cutting
- Maintenance of roadside development

7) Traffic service operations

- Traffic marking
- Maintenance of road signs, guide posts, guard rails, right of way posts, and km. posts
- Maintenance of traffic signals and road lighting

8) Maintenance and repair of structures

- Bridge maintenance and repair
- Miscellaneous structures

9) Emergencies

- Wash outs
- Major landslides
- Major accidents
- Miscellaneous disasters

10) Special maintenance

- Asphalt seal - coating
- Asphalt surface leveling or redressing

- Surface regravelling
- Major repair of asphalt pavement
- Major repair of concrete pavement
- Major repair of shoulders, side road approaches and median strips
- Major side slope repairing
- Dust palliatives

11) Betterments

- Improvement of geometry
- Pavement widening
- Shoulder widening or improvement
- Base stabilization
- Asphalt surfacing
- Upgrading of paved roads
- Replacement or extension of minor structures
- Construction of minor retaining walls
- Elimination of flooding and improvement of drainage
- Erosion protection
- Paving of ditches
- Provision of rest areas
- Provision of bus stops and shelters
- Installation of traffic signals and road lighting
- Installation of guard rail
- Installation of road signs, guide posts, right of way posts, and km. posts
- Roadside clearing
- Planting and landscaping

Table B2

The main factors that affect vehicle running costs may be grouped as follows:

1) The highway

- Distance
- Geometric design, transverse and longitudinal
- Character of roadway surface
- Traffic volume, composition, traffic controls, and speed changes
- Legal restraints

2) The vehicle

- Road weight and weight-horsepower ratio
- Engine design
- Transmission and rear-axle ratios
- Tyre size and tyre pressure
- Vehicle dimensions and vehicle dynamic characteristics
- Mechanical condition of engine, power transmission, and braking systems
- Type of fuel

3) The operator

- Rates of acceleration and deceleration (speed changes)
- Number and range of speed changes
- Number and timing of gear changes
- Cruising speed
- Character of use, trip length, and annual mileage
- Care of vehicle

4) The weather and topography

- Air temperature, air pressure, and air humidity
- Wind direction and velocity
- Rain, snow, and ice conditions on roadway
- Altitude and topography

From: WINFREY, R. (1969)

APPENDIX C

SUMMARY OF MAINTENANCE AND VEHICLE OPERATING COSTS

Table C 1 Maintenance Cost and Vehicle Operating Costs at 5 Percent Traffic Growth

Analysis Year	Maintenance Costs, Baht					Vehicle Operating Costs, Baht				
	Section				Total	Section				Total
	1	2	3	4		1	2	3	4	
4	979	15,134	16,810	21,645	54,568	3,809,551	36,272,332	32,452,828	35,181,463	107,716,173
5	9,050	15,134	16,810	21,645	62,639	4,065,942	38,436,205	34,343,850	37,231,642	114,077,639
6	13,912[1]	59,068	16,810	21,645	111,435	4,349,162	40,799,708	36,373,745	39,432,405	120,955,020
7	91,260	133,916	16,810	21,645	263,631	4,651,366	43,299,782	38,486,714	41,723,227	128,161,089
8	979	139,854	102,883	115,006	358,721	4,971,760	45,871,347	40,643,457	44,061,475	135,548,039
9	14,224	146,088	150,255	166,389	476,956	5,312,969	48,550,578	42,876,745	46,482,694	143,222,986
10	93,397	631,607[2]	999,274[2]	1,087,342[2]	2,811,620	5,676,390	51,371,282	45,214,854	49,017,549	151,280,075
11	1,522	15,134	16,810	21,645	55,111	6,065,553	54,381,706	47,676,942	51,686,824	159,811,025
12	18,303	31,574	16,810	21,645	88,332	6,483,638	57,616,761	50,278,126	54,506,905	168,885,430
				Year 4 ADT		4,762[3]	2,381[3]	1,232	1,232	
				Year 12 ADT		7,036[3]	3,518[3]	1,820	1,820	
				Length, km.		0.8	14.1	24.8	26.9	

[1]Surface dressing required at this time because cumulative traffic loading has exceeded 1.5×10^6 equivalent standard axles

[2]Surface dressing required because 7 years was specified for this study as the maximum duration to first surface dressing treatment

[3]The actual highway volumes on Section 1 and Section 2 are equal. There shown for Section 2 are half of the Section 1 volume as only a 2-lane carriageway was built as new road in Section 2; the old 2-lane carriageway remained in service for northbound traffic.

Appendix Table C 2 Maintenance Costs and Vehicle Operating Costs at 10 Percent Traffic Growth

Analysis Year	Maintenance Costs, Baht					Vehicle Operating Costs, Baht				
	Section					Section				
	1	2	3	4	Total	1	2	3	4	Total
4	1,116	17,532	17,600	24,629	60,877	3,809,551	36,272,332	32,452,828	35,181,462	107,716,173
5	9,723	17,532	17,600	24,629	69,484	4,260,599	40,282,086	35,970,302	38,994,848	119,507,835
6	15,308[1]	77,623	17,600	24,629	135,160	4,754,256	44,626,946	39,733,717	43,074,807	132,189,726
7	93,427[1]	154,101	17,600	24,629	289,757	5,303,401	49,413,362	43,842,164	47,528,801	146,087,728
8	2,326	167,755[2]	164,249[2]	183,694[2]	518,024	5,930,103	54,709,720	48,362,584	52,429,418	161,431,825
9	19,998	661,747[2]	185,986[2]	207,271[2]	1,075,002	6,642,859	60,626,797	53,385,711	57,875,052	178,530,419
10	98,586	17,532	1,045,169	1,139,250	2,300,537	7,457,219	67,294,049	58,997,900	63,959,346	197,708,514
11	8,001	119,709	17,600	24,629	169,939	8,390,797	74,894,258	65,280,440	70,770,440	219,335,935
12	102,943	237,462	17,600	24,629	382,634	9,462,949	83,484,959	72,316,596	78,398,622	243,663,126
				Year 4 ADT		4,762[3]	2,381[3]	1,232	1,232	
				Year 12 ADT		10,208[3]	5,104[3]	2,641	2,641	
				Length, km.		0.8	14.1	24.8	26.9	

[1, 2, 3] See foot note Table C 1

Table C 3 Maintenance Costs and Vehicle Operating Costs at 15 Percent Traffic Growth

Analysis Year	Maintenance Costs, Baht					Vehicle Operating Costs, Baht				
	Section				Total	Section				Total
	1	2	3	4		1	2	3	4	
4	1,116	17,532	17,600	24,629	60,877	3,809,551	36,272,332	32,452,828	35,181,462	107,716,173
5	10,358	17,532	17,600	24,629	70,119	4,455,292	42,128,201	37,597,001	40,758,323	124,938,817
6	16,625[1]	94,295	17,600	24,629	153,149	5,179,345	48,641,666	43,258,097	46,895,441	143,874,549
7	95,651[1]	173,580	48,032	57,636	374,899	6,022,015	56,135,501	49,727,911	53,909,256	165,794,683
8	5,662	196,984[1]	200,467	222,978	626,091	7,036,993	64,887,337	57,241,301	62,054,438	191,220,069
9	101,394	702,870[1]	227,893[2]	252,727[2]	1,284,884	8,254,757	75,189,030	66,031,722	71,584,122	221,059,631
10	12,268	17,532	1,101,781[2]	1,200,655[2]	2,332,236	9,725,168	87,482,890	76,351,636	82,772,053	256,331,747
11	108,991	248,235	17,600	24,629	339,939	11,507,662	102,130,363	88,481,529	95,922,347	298,041,901
12	21,003	810,349	123,886	139,913	1,095,151	13,674,967	119,570,833	102,789,479	111,434,122	347,469,401
				Year 4 ADT		4,762[3]	2,381[3]	1,232	1,232	
				Year 12 ADT		14,567[3]	7,284[3]	3,769	3,769	
				Length, km.		0.8	14.1	24.8	26.9	

[1, 2, 3] See foot note Table C 1

Table C 4 Discounted Maintenance and Vehicle Operating Costs at 5 Percent Traffic Growth, Baht

Analysis Year	Maintenance cost	Discounted at			Vehicle operating cost	Discounted at		
		10%	12%	15%		10%	12%	15%
4	54,568	37,271	34,679	31,199	107,716,173	73,571,596	68,455,576	61,587,072
5	62,639	38,894	35,543	31,143	114,077,639	70,833,239	64,730,717	56,716,748
6	111,435	62,902	56,456	48,176	120,955,020	68,275,956	61,279,579	52,292,193
7	263,631	135,284	119,253	99,109	128,161,089	65,766,903	57,973,569	48,180,500
8	358,721	167,346	144,881	117,267	135,548,039	63,234,161	54,745,581	44,310,894
9	476,956	202,276	171,995	135,581	143,222,986	60,740,527	51,647,646	40,712,911
10	2,811,620	1,084,001	905,266	694,989	151,280,075	58,325,018	48,708,136	37,394,121
11	55,111	19,316	15,843	11,846	159,811,025	56,012,789	45,941,852	34,350,297
12	88,332	28,145	22,673	16,510	168,885,430	53,812,103	43,348,685	31,565,894
Total		1,775,435	1,506,589	1,185,820		570,572,292	496,831,341	407,110,630

Table C 5 Discounted Maintenance and Vehicle Operating Costs at 10 Percent Traffic Growth, Baht

Analysis Year	Maintenance cost	Discounted at			Vehicle operating cost	Discounted at		
		10%	12%	15%		10%	12%	15%
4	60,877	41,580	38,688	34,807	107,715,173	73,571,596	68,455,575	61,587,072
5	69,484	43,144	39,427	34,546	119,507,835	74,204,963	67,811,955	59,416,515
6	135,160	76,294	68,476	58,433	132,189,726	74,617,654	66,971,429	57,149,266
7	289,757	148,694	131,071	108,930	146,087,728	74,966,104	66,082,669	54,919,788
8	513,024	241,662	209,221	169,343	161,431,825	75,309,138	65,199,607	52,772,350
9	1,075,002	455,906	387,656	305,583	178,530,419	75,714,326	64,379,859	50,749,488
10	2,300,537	886,957	740,711	568,658	197,708,514	76,225,191	63,656,850	48,870,521
11	169,939	59,563	48,853	36,527	219,335,935	76,875,907	63,053,840	47,144,773
12	382,634	121,919	98,213	71,517	243,663,126	77,638,581	62,542,255	45,542,380
Total		2,075,719	1,762,316	1,388,344		679,123,460	588,154,039	478,152,154

Table C 6 Discounted Maintenance and Vehicle Operating Costs at 15 Percent Traffic Growth, Baht

Analysis Year	Maintenance cost	Discounted at			Vehicle operating cost	Discounted at		
		10%	12%	15%		10%	12%	15%
4	60,877	41,580	38,688	34,887	107,716,173	73,571,596	68,455,575	61,587,072
5	70,119	43,538	39,787	34,862	124,935,817	77,577,176	70,893,640	62,537,072
6	153,149	86,449	77,590	66,211	143,874,549	81,213,432	72,891,324	62,200,938
7	374,899	192,382	169,585	140,938	165,794,683	85,078,888	74,997,095	62,328,362
8	626,091	292,076	252,868	204,670	191,220,069	89,205,573	77,230,579	62,510,180
9	1,284,884	544,916	463,342	365,244	221,059,631	93,750,863	79,716,319	62,838,944
10	2,332,236	899,178	750,918	576,493	256,331,747	98,826,985	82,531,962	63,361,288
11	339,939	119,147	97,724	73,068	298,041,901	104,461,868	85,679,925	64,062,087
12	1,095,151	348,949	281,098	204,692	347,469,401	110,714,459	89,186,741	64,944,515
Total		2,568,215	2,171,600	1,700,985		814,400,840	701,583,160	565,950,060

APPENDIX D

SUMMARY OF DATA

Table D1 Derivation of Engineering Costs for Saraburi - Lomsak Highway Section 1 (sta. 1+800 to sta. 2+600 = 0.8 km)

1) Horizontal alignment: 0.02 degree / km. measured from the construction plans.

2) Vertical alignment: intersection points and curve lengths as given in the construction plans.

3) Geometric design standards: 5 percent maximum gradient, design speed of 100 km /hr, and 60 meters minimum length of vertical curve.

4) Ground data: measured from the construction plans in terms of elevation at 100 meter chainage intervals.

5) Roadway cross section: roadway width 21.0 meters with crossfall of 1:50 (rise:run); shoulder width of 3.0 meters with crossfall of 1:50 determined from typical cross section. Other cross-section details were estimated average values: cut slope 1:2.5, fill slope 1:2.5, ditch depth 1.0 meter, ditch side slope 1:4. The width of the strip to be cleared of ground cover was 60 meters (the full width of right of way).

6) Soil characteristics: cut material was generally suitable for use as embankment. Earthwork bulking and compaction factors were 1.25 and 0.8, respectively; subgrade CBR was taken to be 5 percent.

7) Earthwork excavation: a unit cost of 24.53 Baht per m^3 was used based on a weighted average of roadway excavation of earth, weathered rock, and rock.

8) Earthwork filling: a unit cost of 17.50 Baht per m^3 was used. (In Thailand earthwork fills or embankments are paid for at unit costs which include fill, haulage, borrow, and spoil.)

9) Earthwork, haulage: zero cost.

10) Earthwork, borrow: zero cost.

11) Earthwork, spoil: zero cost.

12) No retaining walls.

13) Site slearance: 100 percent open country at unit cost of 5600 Baht per ha.

14) Pavement: 4 layers from typical roadway cross section.

(a) 113 mm of selected subgrade (based on weighted average of total of study section) with a unit cost of 34.0 Baht per m^3 from final report.

(b) 200 mm of sub-base (special) with estimated CBR of 20 percent at a unit cost of 150.0 Baht per m^3 from final report.

(c) 150 mm of crushed rock base with estimated CBR of 80 percent at a unit cost of 132.0 Baht per m^3 from final report.

(d) 50 mm of asphaltic concrete pavement at a unit cost of 520.6 Baht per m^3 from final report.

15) Shoulders: 3 layers from typical roadway cross section.

(a) 113 mm of selected subgrade with a unit cost of 34.0 Baht per m^3.

(b) 200 mm of sub-base with a unit cost of 50.0 Baht per m^3.

(c) 200 mm of soil aggregate shoulder with a unit cost of 60.0 Baht per m^3.

16) Rainfall: average annual rainfall of 1457 mm and maximum hourly rainfall of 79 mm from the final report.

17) Culverts: all reinforced concrete pipe.

(a) 0.50 m diameter at a unit cost of 290.0 Baht per meter length.

(b) 0.60 m diameter at a unit cost of 355.0 Baht per meter length.

(c) 0.80 m diameter at a unit cost of 600.0 Baht per meter length.

(d) 1.00 m diameter at a unit cost of 900.0 Baht per meter length.

(e) 1.20 m diameter at a unit cost of 1300.0 Baht per meter length.

18) Average length of pipe is zero (no reinforced-concrete culverts required in Section 1).

19) Headwalls: unit cost of 1200.0 Baht per m^3.

20) No cross-flow drainage.

21) No minor river crossings.

22) No major river crossings, but allow an additional cost of drainage of 394,056.0 Baht.

23) Miscellaneous costs are 709,457.0 Baht based on a proportion of total.

24) Overheads: zero.

Section 2 (sta. 2+600 to sta. 16+700 = 14.1 km)

1) Horizontal alignment: 2.38 degree/km measured from the construction plans.

2-4) As for Section 1.

5) Roadway cross section: roadway width 7.5 meters with crossfall of 1:50, shoulder width of 2.0 meters with crossfall of 1:25 determined from typical cross section. Other cross section details were estimated, average value: cut slope 1:2.5, fill slope 1:2.5, ditch depth 1.0 meter, ditch side slope 1:4. The width of strip to be cleared of ground cover was 60 meters measured from the construction plans.

6 - 13) As for Section 1.

14) Pavement: 4 layers from typical roadway cross section.

(a) As for Section 1.

(b) 200 mm of sub-base with estimated CBR of 20 percent at a unit cost of 50.0 Baht per m^3 from final report.

(c-d) As for Section 1.

15 - 17) As for Section 1.

18) Average length of pipe is 15.29 meters from construction plans.

19) As for Section 1.

20) Cross-flow drainage: the size most commonly used is 1.20 meters diameter at an average spacing of 671 meters from the construction plans.

21) No minor river crossings.

22) Major river crossings at:

sta. 6+981 RC.Bridge length 30.50 m (3 - 10.00 spans) x 11.00m; skew 0°

sta. 15+206 RC.Bridge length 30.50 m (3 - 10.00 spans) x 11.00m; skew 0°

Costs estimated to be 1,240,496 Baht, from the bills of quantities.

23) Miscellaneous costs are 594,565 Baht based on a proportion of total.

24) Overheads: zero.

Section 3 (sta. 16+700 to sta. 41+500 = 24.8 km)

1) Horizontal alignment: 11.88 degree/km measured from the construction plans.

2) As for Section 1.

3) Geometric design standards: 8 percent maximum gradient, design speed of 60 km/hr, and 60 meters minimum length of vertical curve.

4) As for Section 1.

5) As for Section 2: except cut slope is 1:0.8 (rise:run)

6-13) As for Section 1.

14) As for Section 2.

15-17) As for Section 1.

18) Average length of pipe is 23.57 meters from construction plans.

19) As for Section 1.

20) No cross-flow drainage.

21) Minor river crossings at:

Station	Catchment area, ha	Terrain run-off coeff.
17+662	46.0	0.8
18+733	5.0	0.8
19+002	12.0	0.8
19+747	21.0	0.8
25+500	17.0	0.8
26+250	21.0	0.8
28+150	30.0	0.8
28+275	28.0	0.8
30+200	40.0	0.8
34+460	15.0	0.8

22) Major river crossings at:

	Station	Length	Spans	Width	Skew
RC. Bridge	17+303	40.50	4-10.00	9.00	0°
RC. Box culvert	19+214	width = 5.75; 2 boxes 2.50x2.00; length = 59.0; skew = 0°			
RC. Bridge	20+177	30.532	3-10.00	9.00	20°
RC. Bridge	22+315	30.500	3-10.00	9.00	0°

	Station	Length	Spans	Width	Skew
RC. Bridge	23+179	24.532	3-8.00	9.00	20°
RC. Box culvert	24+514	width = 10.132; 3 boxes 2.50x2.00; length = 30.0; skew=35			
RC. Bridge	26+025	40.578	4-10.00	9.00	30°
RC. Bridge	29+600	30.500	3-10.00	9.00	0°
RC. Bridge	33+973	30.578	3-10.00	9.00	30°
RC. Bridge	36+600	40.500	4-10.00	9.00	0°
RC. Bridge	41+357	30.500	3-10.00	9.00	0°

Costs estimated to be 6,084,843 Baht from the bills of quantities.

23) Miscellaneous costs are 1,008,200 Baht based on a proportion of total.

24) Overheads: zero.

Section 4 (sta. 41+500 to sta. 68+400 = 26.9 km)

1) Horizontal alignment: 6.32 degree/km measured from the construction plans.

2) As for Section 1.

3) Geometric design standards: as for Section 3, except design speed of 65 km/hr.

4) As for Section 1.

5) As for Section 2.

6-13) As for Section 1.

14) As for Section 2.

15-17) As for Section 1.

18) Average length of pipe is 21.89 meters from construction plans.

19) As for Section 1.

20) No cross-flow drainage.

21) Minor river crossings at:

Station	Catchment area, ha	Terrain run-off coeff.
42+000	25.0	0.8
44+260	57.0	0.8
45+300	20.0	0.8
45+850	20.0	0.8
46+275	9.0	0.8
46+900	37.0	0.8
51+135	20.0	0.8
51+550	20.0	0.8
52+855	45.0	0.5

22) Major river crossings at:

	Station	Length	Spans	Width	Skew
RC. Bridge	43+152	30.508	3-10.00	9.00	10°
RC. Bridge	49+140	24.532	3-8.00	9.00	20°
RC. Bridge	50+719	24.500	3-8.00	9.00	0°
RC. Bridge	53+200	18.500	3-6.00	9.00	20°
RC. Bridge	54+740	21.500	3-7.00	9.00	20°
RC. Bridge	55+577	40.500	4-10.00	9.00	10°
RC. Bridge	56+863	40.500	4-10.00	9.00	30°
RC. Bridge	58+291	40.500	4-10.00	9.00	20°
RC. Box culvert	59+242	width = 8.30; 3 boxes 2.50x2.00; length = 15.30; skew = 0°			
RC. Bridge	62+045	40.500	4-10.00	9.00	0°
RC. Bridge	64+594	30.500	3-10.00	9.00	0°

	Station	Length	Spans	Width	Skew
RC. Bridge	66+500	40.500	4 - 10.00	9.00	0°

RC. Box culvert 68+080 width = 8.30; 3 boxes 2.50x2.00; length = 14.4; skew = 0°

Costs estimated to be 6,250,735 Baht from the bills of quantities.

23) Miscellaneous costs are 1,094,925 Baht based on a proportion of total.

24) Overheads: zero.

Details of Structures Costs, Baht

Furnish and drive concrete test piles	17,120
Furnish and drive concrete piles	409,880
Test loading concrete piles	54,000
Concrete for structures Class "A" bridges, box culverts	6,488,270
Reinforcement for bridges and box culverts	3,140,975
Railing, reinforced concrete	55,050
Granular backfill material	177,021
Channel and structural excavated earth	624,494
Channel and structural excavated rock	50,900
Grouted riprap	1,192,440
Other costs of culverts	1,759,980
Total costs	13,970,130

These costs obtained from the bills of quantities and final report.

Miscellaneous Costs, Baht

Removal of existing structures	112,300
Alterations to Pasak River Bridge	140,000
Concrete curb, gutter and sidewalk (Section 1)	536,934

Right-of-way monuments	40,880
Delineators	79,110
Bench marks	5,800
Kilometer posts	25,160
Furnish and erect road signs	12,060
Furnish and install sign posts	50,160
Highway stripping, reflectorized	531,523
Marking at bridge ends	23,700
Furnish and install settlement platforms	1,200
Overhead charge for under-runs	234,071
Force account	23,350
Contract change orders	1,590,899
Total costs, obtained from the final report	3,407,147

Table D 2 Vehicle Operating Costs for Saraburi-Lomsak Highway

1) Interest rate on capital used to buy new vehicles is 12 percent per annum.

2) Fuel prices: the economic cost of fuel was based on Road User Costs in Thailand-1973 by T.P.O'Sullivan & Partners, and gave petrol at 1.20 Baht per liter and diesel fuel at 0.90 Baht per liter. Lubricants were taken at 7.10 Baht per liter.

3) Vehicle maintenance labour rates were taken from average wage of a mechanic, includes the materials, machinery, overheads, and profit associated with labour in the garage business and found to be 32.80 Baht per hour (T.P.O'Sullivan & Partners, 1973)

4) 6 vehicle types were considered in the present study: (1) cars and taxis; (2) light trucks; (3) light buses; (4) heavy buses; (5) 2-axle heavy trucks; and (6) 3-axle heavy truck.

5) For heavy trucks: information on unladen and laden weight and equivalence factors were obtained from 4-day axle-load survey. The results are given in Table E1 and Table E2.

6) For each vehicle class, average new vehicle prices and replacement tyre prices were obtained from Road User Costs in Thailand-1973. These are given in Table E3.

7) Details of operation of the vehicle were obtained largely from Road User Costs in Thailand-1973. The values used are given in Table E4.

8) Figures for average daily traffic in the two directions were obtained from Traffic Volumes and Flow Maps; Planning Division, Highway Department.

Table D3 Road Maintenance Data for Saraburi - Lomsak Highway

Plant hire rates (Baht per hour): these rates were obtained from Mechanical Division, Highway Department

4500 - liter bitumen distributor	110.0
0.25 - tonne vibrating roller	20.0
Motor grader	110.0
10 - tonne roller	45.0
Tractor mower	50.0
Water tanker	67.5
Tipper truck	67.5

Labour rates (Baht per hour): these rates were obtained from Economic Feasibility Study (DE LEUW, CATHER, 1964)

Labourers	4.0
Truck drivers	5.0
Plant operators	8.0
Foremen	10.0

Material costs: these costs were obtained from Final Report (De Leuw, Cather, 1970) and Rural Road Project (Ministry of Interior, 1971)

Bitumen	1.5 Baht per liter
Surface dressing stone	132.0 Baht per m^3
Base patch material	132.0 Baht per m^3
Surface patch mix	350.0 Baht per m^3
Diesel fuel	1.0 Baht per liter

Transport distances :

Bitumen	20 km
Surface dressing stone	20 km
Depot to site	20 km

APPENDIX E

Table E 1 Heavy Trucks by Weight

Gross Weight, tonnes	Number of Heavy Trucks							
	Saraburi - Ban Phu Kae				Ban Phu Kae - Lamnarai			
	SB		NB		SB		NB	
	2-axle	3-axle	2-axle	3-axle	2-axle	3-axle	2-axle	3-axle
5.5 - 6.5			8				11	
6.5 - 7.5	2		1	110	1			52
7.5 - 8.5	1		5					
8.5 - 9.5			2					
9.5 - 10.5	10		7		8		1	
10.5 - 11.5	11		2		3			
11.5 - 12.5	2		1	1	1		1	1
12.5 - 13.5				1				
13.5 - 14.5				1				
14.5 - 15.5		1		2				2
15.5 - 16.5		3		1		2		1
16.5 - 17.5		6		8		3		4
17.5 - 18.5		85		11		39		1
18.5 - 19.5		4		1		3		
19.5 - 20.5		37		1		12		1
20.5 - 21.5		1				3		

Table E2 Heavy Truck Descriptions

Item		Saraburi - Ban Phu Kae			Ban Phu Kae - Lamnarai		
		Heavy bus	2 - axle	3 - axle	Heavy bus	2 - axle	3 - axle
Brake horse power		185	125	125	185	125	125
Unladen weight, tonnes		7.0	5.5	7.2	7.0	5.5	7.2
Direction	Load, tonnes	2.0	4.7	11.3	2.0	4.5	11.2
Southbound	Equivalence factor	0.23	0.45	1.32	0.23	0.41	1.27
Direction	Load, tonnes	2.0	2.6	1.9	2.0	0.8	1.5
Northbound	Equivalence factor	0.23	0.22	0.20	0.23	0.11	0.15

Table E3 Vehicle and Tyre Prices, (Economic Costs), Baht

Vehicle Type	New Vehicle Price	Replacement Tyre Price
Cars and taxis	62,000	1,400
Light trucks	58,000	2,200
Light buses	62,000	2,200
Heavy buses	330,000	8,200
2 - axle trucks	168,500	8,200
3 - axle trucks	194,200	13,700

Table E4 Vehicle Crews, Usage, Passengers' Time and Overheads

Vehicle Type	Number of crew	Crew cost per hour	Av. annual crew hour	Passenger's time B/hr	Av. annual kilometers	Standing cost, %
Cars and taxis	0	-	0	30.0	18,000	10
Light trucks	1	6.0	1,500	10.0	25,000	25
Light buses	1	6.0	2,500	20.0	35,000	25
Heavy buses	2	10.0	5,500	50.0	70,000	25
2 - axle trucks	1	6.0	5,500	7.0	70,000	25
3 - axle trucks	1	6.0	5,500	7.0	70,000	25

Table E5 Traffic Flows on Saraburi - Lomsak Highway in 1970

(By Exponential Regression)

Vehicle type	Average Daily Traffic			
	Section 1	Section 2[1]	Section 3	Section 4
Cars and taxis	1,590	795	273	273
Light trucks	448	224	164	164
Light buses	367	183	118	118
Heavy buses	448	224	107	107
2 - axle trucks	700	350	200	200
3 - axle trucks	1,209	605	370	370
Total	4,762	2,381	1,232	1,232

[1]Two lanes, only Southbound direction, taken as half of ADT on Section 1.

VITA

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