CHAPTER III

COLLECTING DATA AND DATA ANALYSIS

To achieve the objectives of the research, in this chapter will be categorized into 2 steps as following:

1. Total costs estimation and analysis of factors affecting total costs of pavement in-place recycling of DOH & DOR.

2. Total costs estimation and analysis of factors affecting total costs of pavement in-place recycling of the contractor.

Data for total costs estimation of DOH and DOR can be collected from Bureau of Highways Maintenance Management Department of Highways and Bureau of Maintenance and Traffic Safety Department of Rural Roads respectively. Data for total costs estimation of the contractor can be collected by studying in the field and interview two contractors. The analysis of factors can be done by defining example projects of DOH & DOR.

3.1 Total Costs Estimation in Pavement In-Place Recycling of DOH & DOR

Total costs estimation of road construction of DOH & DOR has steps as following:

1. Consider quantity of work from general drawings.

2. Calculate direct costs (unit cost) of each work list from standard estimation. Then calculate direct costs (price) of each work list (direct costs × quantity of work)

3. Sum direct costs (price) of all work lists in road construction. Taking sum direct costs (price) interpolates in Factor F tables to find Factor F.

4. Taking Factor F multiply with direct costs (unit cost) of each work list to become total costs (unit cost) of each work.

5. Taking total costs (unit cost) multiply with quantity of work become total costs (price) of each work.

6. Sum total costs (price) of all work lists to become total costs of project.

The direct costs of pavement in-place recycling of DOH & DOR can be calculated from a formula as shown in equation 3.1.

$$N = F1 \text{[Machine Operation Costs + Depreciation Costs} + AY + SC] \quad (3.1)$$

By N = Direct costs of pavement in-place recycling (Baht/m^2)

$F1$ = Traffic Factor

Use 1.006 for traffic less than 1,000 vehicles/day

Use 1.003 for traffic more than 1,000 vehicles/day

A = Amount of asphalt (Ton/ m^2) (Table 3.1, 3.2)

Y = Asphalt prices (included delivery cost) (Baht/ton)

S = Amount of cement (Ton/ m^2) (Table 3.1, 3.2)

C = Cement prices (included delivery cost) (Baht/ton)

Factors use for consideration with direct costs formula are recycling depth, amount of asphalt or cement (% by RAP weight), and specific weight of reclaimed asphalt material (RAP). DOH & DOR define the recycling depth at 20 cm. and use only Portland cement type I as a stabilizing agent. DOH defines the amount of cement at 4% by RAP while DOR defines the amount of cement at 3.5% by RAP as shown in Tables 3.1 and 3.2.

Table 3.1 Amount of asphalt/cement used at different depth for DOH

Recycling depth	Quantity of asphalt (A) (Ton/m^2)			Quantity of cement (S) (Ton/m^2)			
	1%	2%	3%	2%	3%	4%	5%
10	0.0023	0.0046	0.0069	0.0046	0.0069	0.0092	0.0115
15	0.0035	0.0069	0.0104	0.0069	0.0104	0.0138	0.0171
20	0.0046	0.0095	0.0138	0.0095	0.0138	0.0184	0.0230
25	0.0058	0.0115	0.0173	0.0115	0.0173	0.0230	0.0288
30	0.0069	0.0138	0.0207	0.0138	0.0207	0.0276	0.0345

Source: Highways standard office DOH

Table 3.2 Amount of asphalt/cement used at different depth for DOR

Recycling depth	Quantity of asphalt (A) (Ton/m^2)			Quantity of cement (S) (Ton/m^2)			
	1%	2%	3%	2%	3%	3.5%	4%
10	0.0022	0.004	0.007	0.004	0.007	0.008	0.009
15	0.0033	0.007	0.010	0.007	0.010	0.012	0.013
20	0.0044	0.009	0.013	0.009	0.013	0.015	0.018
25	0.0055	0.011	0.017	0.011	0.017	0.019	0.022
30	0.0066	0.013	0.020	0.013	0.020	0.023	0.026

Source: Bureau of Maintenance and Traffic Safety DOR

From the steps of total costs estimation and the formula of direct costs of pavement in-place recycling, we can draw flow chart of total cost estimation in pavement in-place recycling as shown in Figure 3.1. From the figure, we can find that direct costs formula consists of traffic factor value, machine operation costs, depreciation costs, and cement costs.

1. Traffic Factor Value

Traffic factor depends on traffic condition. This factor is used to multiply with direct cost. The traffic is less than 1,000 vehicles/day used 1.006 and the traffic is more than 1,000 vehicles/day used 1.003.

2. Machine Operation Costs and Depreciation Costs

Machine operation costs and depreciation costs of pavement in-place recycling can calculate from ownership costs and operating costs as following:

Ownership Costs = Investment Costs + Depreciation Costs

Investment Costs

New machine prices (not included tires)		P	Baht	
Salvage value of machine	S =	0.10 P	Baht	(3.2)
Useful life		N	years	
Investment interest rate		R	7% per year	
Insurance rate		I	3% per year	

Percentage of cement → Amount of cement

Recycling depth

Investment costs → Fixed costs

Tire costs

Maintenance costs

Operator costs

Factory prices → Cement prices

Delivery costs

New machine prices

Salvage value

Useful life

Fuel Costs → Running costs

Lubricant costs

Labor costs

Normal/Rainy

Traffic factor value | Machine operation costs | Depreciation costs | Cement costs

Operating rate

1) Quantity of Pavement in-place recycling work

1) Direct Costs (unit cost) of Pavement in-place recycling

2) Quantity of other pavement structure repairing works
3) Quantity of pavement surface work
4) Quantity of pavement shoulder work
5) Quantity of traffic lines work
6) Quantity of traffic marks work

2) Direct costs (unit cost) of other pavement structure repairing work
3) Direct costs (unit cost) of pavement surface
4) Direct costs (unit cost) of pavement shoulder
5) Direct costs (unit cost) of traffic lines
6) Direct costs (unit cost) of traffic marks

1) Direct costs (price) of pavement in-place recycling
2) Direct costs (price) of other pavement structure repairing works
3) Direct costs (price) of pavement surface
4) Direct costs (price) of pavement shoulder
5) Direct costs (price) of traffic lines
6) Direct costs (price) of traffic marks

Sum direct costs (price) of all works

Normal/Rainy1/Rainy2

Factor F

Total costs (unit cost) of pavement in-place recycling

Total costs (price) of pavement in-place recycling

Figure 3.1 Flow chart for total costs estimation in pavement in-place recycling

$$\text{Average value of machine} \quad P_{av} = [P(N+1) + S(N-1)] / 2N \quad \text{Baht/year}$$

$$= 0.55 P + 0.45 P/N \quad \text{Baht/year}$$

$$\text{Investment costs} \quad = (R + I) P_{av} \quad \text{Baht/year}$$

$$= 0.08 (0.55 P + 0.45 P/N) \text{Baht/year} \quad (3.3)$$

Depreciation Cost

By the straight line method

$$\text{Depreciation Costs} \quad D = (P - S) / N \text{ Baht/year}$$

$$= 0.9 P/N \quad \text{Baht/year} \quad (3.4)$$

Operating costs consist of fuel costs, lubricant and filter costs, maintenance and repair costs, tire and high-wear items costs, and operator costs.

Fuel Costs

Diesel engine $\quad = 0.10 \quad$ Liter/hour/HP

Or fuel consumption rate $\quad = 0.22 \quad$ Liter/hour/HP × efficiency

Efficiency is between $0.5 - 0.9$ that depends on working condition and type of machines

Lubricant Costs

Lubricant consumption rate $= 0.002 \, HP + 0.038C \quad$ (Baht/hour)

By C is capacity of lubricant (Liter)

Or lubricant costs $\quad = 0.15 \quad$ Fuel costs

Maintenance and Repair Costs

Maintenance costs $= 0.05 - 0.20 \,$ Baht/HP/hour depends on type of machines

Repair costs $= \quad$ Repair factor × Depreciation costs (Baht/hour)

Or maintenance and repair costs $= R/1,000 \times$ new machine prices (Baht/hour)

Repair factor depends on type of machines and working condition as shown in Table 3.3

Table 3.3 Repair factor of machines

Repair Factor	Working condition		
	Soft	Medium	Hard
Tractor	0.07	0.09	0.13
Scrapper	0.09	0.13	0.17
Loader	0.04	0.06	0.09
Backhoe	0.04	0.06	0.08
Grader	0.03	0.05	0.07
Roller	0.04	0.06	0.08
Truck	0.06	0.08	0.11

Source: Highways standard office DOH

Tire and High-Wear Items Costs

$$\text{Tire and parts costs} \quad = \quad \frac{\text{Tire and parts prices}}{\text{Tire and parts life}} \quad \text{(Baht/hour)} \qquad (3.5)$$

Operator Costs

Operator costs can be shown in Table 3.4

Table 3.4 Machine operator wage

Type of machines	Baht/month	Baht/day	Baht/hour
Tractor	8,400	280	40.00
Grader	13,500	450	64.29
Loader	7,300	243	34.76
Backhoe	7,900	263	37.62
Roller	6,200	207	29.52
Truck + Labor	7,000 + 4,500	383	54.76
Labor	4,900	163	23.33

Source: Highways standard office DOH

When defines type of machines, HP, useful life, new machine prices, and working hour per year of machines used in pavement in-place recycling, we can calculate ownership costs and operating costs of the machines as shown in Table 3.5. The ownership costs and operating costs in Table 3.5 is in case that fuel costs is 15.50 Baht/liter and interest rate at 7% per year.

Table 3.5 Ownership costs and operating costs for fuel price at 15.50 Baht/liter

No.	Type of machines	HP	Useful life (Year)	Working hour per year (Hour)	New machine prices (Baht)	Ownership costs		Tire prices (Baht)	Tire life (Hour)	Operating costs					Operator costs (Baht/hr.)	Total (Baht/hr.)
						Investment costs (Baht/hr.)	Depreciation costs (Baht/hr.)			Tire costs (Baht/hr.)	Fuel costs (Baht/hr.)	Lubricant costs (Baht/hr.)	repair factor	Maintenance costs (Baht/hr.)		
1	Cold Recycler	601	6	2,000	48,384,000	1,209.60	3,628.80	-	-	-	931.55	139.7325	0.10	4,838.40	93.75	7,213.03
2	Steel Wheel Compact	130	6	2,000	3,500,000	87.50	262.50	-	-	-	201.50	30.225	0.06	210.00	22.50	551.73
3	Rubber Tire Roller	80	10	2,000	3,200,000	76.16	144.00	51,405	1,500	34.27	124.00	18.6	0.05	160.00	29.52	442.55
4	Cement Truck	150	12	2,000	2,250,133	52.88	84.38	32,640	1,200	27.2	232.50	34.875	0.08	180.00	46.88	574.34
5	Water Truck	150	10	2,000	2,300,000	54.74	103.50	32,640	1,200	27.2	232.50	34.875	0.08	184.00	54.76	588.08
	Total				59,634,133	1,480.88	4,223.18	116,685		88.67	1,722.05	258.31		5,572.40	247.41	9,369.73

Source: Bureau of Standard DOH

Remarks:
1. Average Zola fuel prices   =   15.50   Baht/liter
2. Average Benzene fuel prices   =   21.00   Baht/liter
3. Minimum daily labor wage   =   149.36   Baht
4. New machine prices in 2005

From Table 3.5, we can consider fixed costs and running costs of pavement in-place recycling as shown in Tables 3.6 and 3.7.

Table 3.6 Fixed costs of pavement in-place recycling machines

Type of machine	Investment costs (Baht/hr.)	Depreciation costs (Baht/hr.)	Tire prices (Baht)	Repair factor	Maintenance costs (Baht/hr.)	Operator costs (Baht/hr.)	Fixed cost (F) (Baht/hr.)
Cold recycling	1,209.60	3,628.80	–	0.10	4,838.40	93.75	9,770.55
Steel wheel compact	87.50	262.50	–	0.06	210.00	22.50	582.50
Rubber tire roller	76.16	144.00	34.27	0.05	160.00	29.52	443.95
Cement truck	52.88	84.38	27.2	0.08	180.00	46.88	391.34
Water truck	54.74	103.50	27.2	0.08	184.00	54.76	424.20
Total cost	1,480.88	4,223.18	88.67		5,572.40	247.41	11,162.54

Source: Highways standard office DOH

Table 3.7 Running costs of pavement in-place recycling machines

Type of machine	HP	Fuel costs (Baht/hr.)	Lubricant costs (Baht/hr.)	Number	Running cost (R) (Baht/hr.)
Cold recycling	601	931.55	139.7325	1	1,071.28
Steel wheel compact	130	201.50	30.225	1	231.73
Rubber tire roller	80	124.00	18.6	1	142.60
Cement truck	150	232.50	34.875	1	267.38
Water truck	150	232.50	34.875	1	267.38
Total cost		1,722.05	258.31		1,980.36

Source: Highways standard office DOH

Machine operation costs and depreciation costs can find from Tables 3.6 and 3.7 by defining an average Zola fuel price = 15.50 (Baht/liter), minimum daily labor wage L = 149.36 Baht/day/man, working hours = 8 hours/day, cold recycler working hours = 3.5 hours/day, roller working hours = 3.5 hours/day, fixed cost of machines F = 8 hours, and running cost of machines R = 3.5 hours. Machine operation costs and depreciation costs can calculate as following:

1. Running cost

$$= 3.5 \times R = 3.5 \times 1,980.36 = 6,931.25 \quad \text{Baht/day}$$

2. Fixed costs

$$= 8 \times F = 8 \times 11,162.54 = 92,900.22 \text{ Baht/day}$$

3. Labor costs

$$= 10 \times L = 10 \times 149.36 = 1,493.60 \text{ Baht/day}$$

4. Depreciation costs

$$= 8 \times D = 8 \times 4,223.18 = 33,785.44 \text{ Baht/day}$$

5. Machine operation costs

$$= 6,931.25 + 92,900.22 + 1,493.60 - 33,785.44 = 67,539.73 \text{ Baht/day}$$

Considering cold recycler operating at recycling depth 20 cm. that has working rate at 6 m./minute or 360 m./hour or 720 m^2/hour or 2,520 m^2/day can calculate machine operation costs and depreciation costs as following:

Machine operation costs $67,539.73/2,520 = 26.80$ Baht/m^2

Depreciation costs. $33,785.44/2,520 = 13.41$ Baht/m^2

Machine operation costs and depreciation costs in pavement in-place recycling in case any fuel prices and any recycling depth can find from Table A.1 in Appendix A

3. Cement Costs

DOH & DOR use cement prices from wholesales prices of manufacturer in each location. The monthly prices lists of Portland cement type I can consider from Bureau of Index Prices Department of Commerce as shown in Table 3.8.

Delivery costs can find from Tables that classified by type of truck and fuel prices levels from 15.00 – 39.99 Baht/liter. In case fuel price is range from 25.00 – 25.99 Baht/liter can be shown in Table A.2 and in case fuel price is range from 29.00 – 29.99 Baht/liter can be shown in Table A.3 in Appendix A.

Table 3.8 Monthly prices of Portland cement type I at factory (not include VAT) in 2007

No.	Portland cement type I	Unit	Monthly prices at factory (Baht/ton)												Average
			Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	
1.	Elephant (Saraburee)	Ton	2,306.00	2,306.00	2,364.00	2,364.00	2,364.00	2,364.00	2,364.00	2,364.00	2,364.00	2,364.00	2,364.00	2,480.00	2,364.00
2.	Naga green (Taklee)	Ton	2,306.00	2,306.00	2,306.00	2,306.00	2,306.00	2,306.00	2,306.00	2,306.00	2,306.00	2,194.00	2,194.00	2,294.00	2,286.33
3.	Diamond (Saraburee)	Ton	2,306.00	2,306.00	2,306.00	2,306.00	2,306.00	2,306.00	2,306.00	2,306.00	2,306.00	2,306.00	2,306.00	2,344.00	2,309.17
4.	TPI red (Saraburee)	Ton	2,306.00	2,306.00	2,306.00	2,306.00	2,306.00	2,306.00	2,306.00	2,306.00	2,306.00	2,306.00	2,306.00	2,306.00	2,306.00
5.	Mountain (Saraburee)	Ton	2,306.00	2,306.00	2,306.00	2,306.00	2,306.00	2,306.00	2,306.00	2,306.00	2,306.00	2,194.00	2,194.00	2,294.00	2,286.33
6.	Elephant (Lumpang)	Ton	2,346.00	2,346.00	2,404.00	2,404.00	2,404.00	2,404.00	2,404.00	2,404.00	2,404.00	2,404.00	2,404.00	2,526.00	2,404.50
7.	Elephant (Tungsong)	Ton	2,416.00	2,416.00	2,484.00	2,484.00	2,484.00	2,484.00	2,484.00	2,484.00	2,484.00	2,484.00	2,484.00	2,606.00	2,482.83

Source: Bureau of Index Prices Department of Commerce

From flow chart for total cost estimation in pavement in-place recycling as shown in Figure 3.1, it can find that costs affecting machine operation costs consists of 3 items: fixed costs, running costs, and labor cost. In addition machine operation costs also depend on operating rate.

Costs affecting fixed costs consist of 4 items: investment costs, tire costs, maintenance costs, and operator costs. Costs affecting running costs consists fuel costs and lubricant costs. The fuel costs depend on 2 factors: power of machine (HP) and fuel prices. The factors affecting labor cost are daily labor wage and numbers of labor.

Factors affecting investment costs consist of 5 factors: new machine prices, machine service life, investment interest, insurance, and working hours per year. The tire costs depend on tire prices and tire life. The maintenance costs depend on repair factor and new machine prices. The operator costs depend on type of machines.

From flow chart for total cost estimation in pavement in-place recycling as shown in Figure 3.1, it can find that factors affecting depreciation costs consists of 3 factors: new machine prices, salvage value, and machine service life. The depreciation costs can be classified in to 2 cases depending on weather condition which are normal rain and rainy. In case rainy, the depreciation costs will be increased 25% from normal rain case. In addition depreciation costs also depend on operating rate.

From flow chart for total cost estimation in pavement in-place recycling as shown in Figure 3.1, it can find that factors affecting cement costs are cement prices and amount of cement. The amount of cement depends on percent of cement and recycling depth. The cement prices depend on factory prices and delivery costs.

Generally, total cost in road construction can be divided into 2 parts that are direct costs and operation costs (indirect costs). The direct costs can find from considering quantity of work from general drawings and calculate direct costs (unit costs) of each work from standard estimation. The direct costs (price) of each work can be calculated by multiply direct costs (unit costs) with quantity of work. Summation of all direct costs (price) in project will be costs of project. The operation costs can find from Factor F. The operation costs consist of 4 items: administrative costs, interest costs, profit, and VAT.

Factor F of the project can find from Factor F tables as shown in Figures B.1 – B.12 in Appendix B. The calculation of costs in Factor F is explained in Appendix C. In addition weather condition in site location also affects operation costs. In rainy area or having rainy season more than other area will has working hours less than dry area. Making administrative cost in rainy area is higher and affects to ownership costs especially in depreciation cost of machines. Therefore, there are addition costs in Factor F for rainy area. Consequently, Factor F is classified in 3 cases that are Factor F (Normal), Factor F (Rainy1), and Factor F (Rainy2).

The operation costs that can be finding from Factor F can consider in chart of component of factors affecting operation costs for normal rain case and rainy case as shown in Figure 3.2 and 3.3 respectively. It can find from the Figures that operation costs consist of administrative costs, interest costs, profit, and VAT. Costs affecting administrative costs consist of 4 items: contracting costs, site office and vehicles costs, staff and headquarter costs, and risk costs. In case of rainy, there is addition item to the administrative costs that is addition administrative costs.

From Figure 3.2 and 3.3, it can find that costs affecting contracting costs consist of 4 items: performance bond fee, guarantee bond fee, stamp fee, and social insurance fund. Costs affecting site office and vehicles costs consists of 2 items: site office costs and vehicles costs. Costs affecting staff and headquarter costs consists of 2 items: staff costs and headquarter costs. Costs affecting risk costs consist of 2 items: insurance costs and other risk costs. In case of rainy, there is addition item to the risk costs that is addition risk costs.

Factors affecting interest costs consist of 3 factors: interest rate, advance payment, and retention money. In case of rainy, there is an addition factor to the interest costs that is addition interest rate.
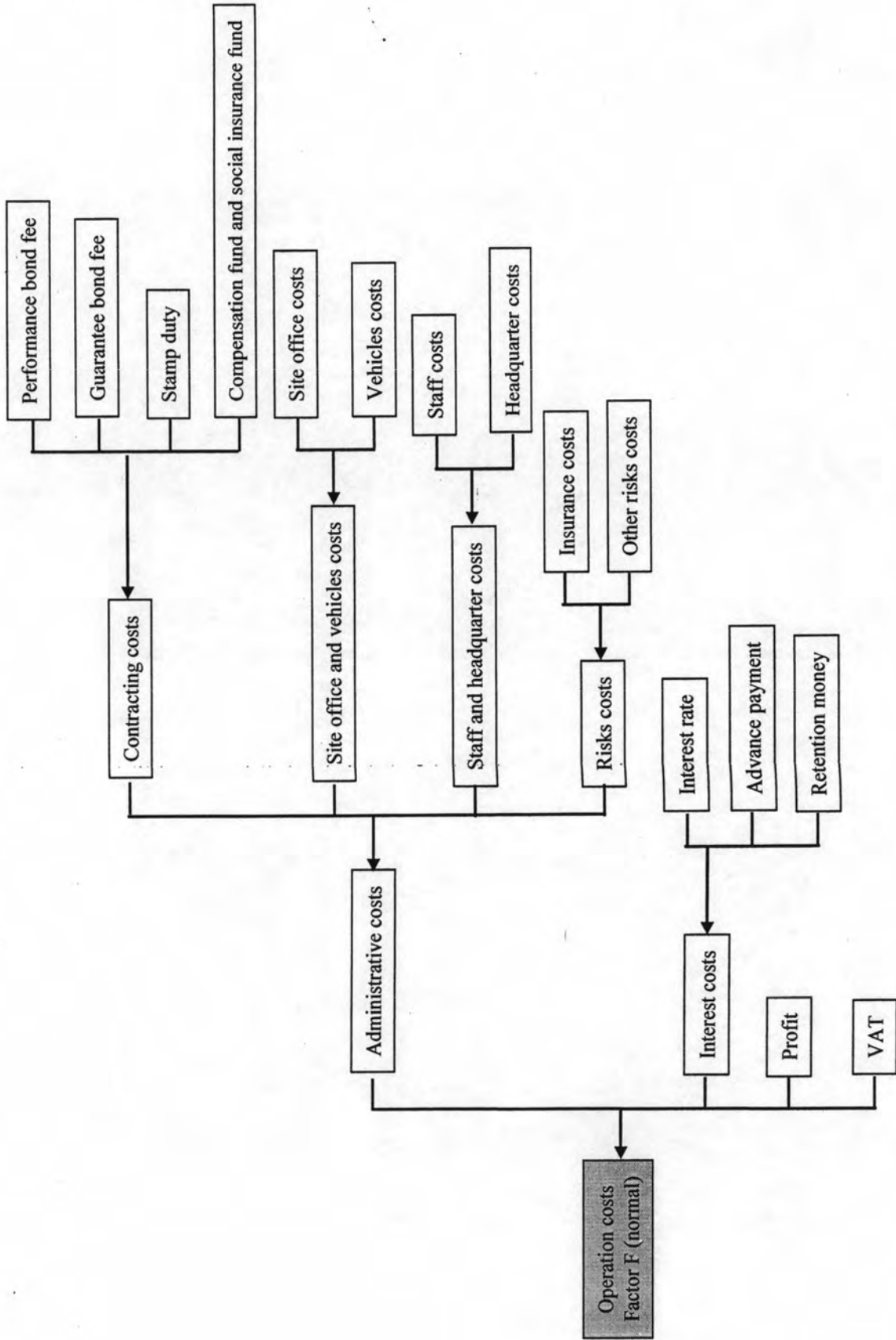
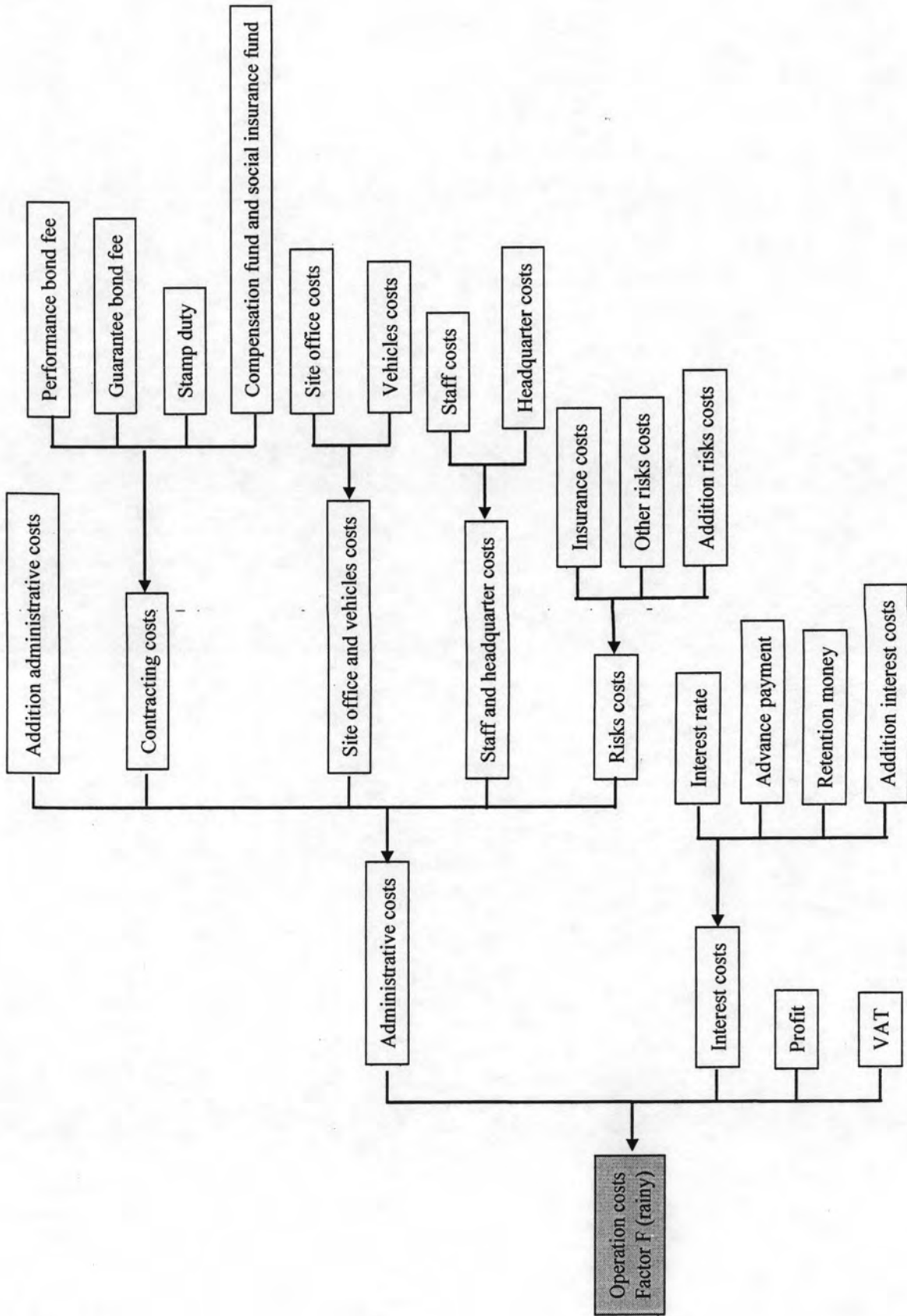Figure 3.2 Component of factors affecting operation costs (Factor F normal)

Figure 3.3 Component of Factors Affecting Operation Costs (Factor F Rainy)

3.1.1 Total Costs Estimation in Pavement In-Place Recycling in the Example Project of DOH

Total costs estimation in pavement in-place recycling of DOH can be shown by defining the example project as following:

Example project:

Owner: Bureau of Highways Maintenance Management Department of Highways

Responsible part: Stun Highways District

Type of work: Pavement In-Place Recycling

Start date: 20 December 2007

Job detail:

Work code: 4100 Name: Highways 4501

Junction part: Stun Municipality – Jebilung Subdistric Administrative Organization

Location: Stun province

Repair distance: 6.617 km.

Range: km. 5+283 to km. 11+900

Weather condition: Rainy

Average Zola fuel prices: 29.50 Baht/liter

Advance payment: 15.0 %

Retention money: 10.0 %

Interest rate: 7.0 %

VAT: 7.0 %

Material Prices and Delivery Costs

Table 3.9 Material prices and delivery costs in the example project of DOH

No.	Item	Source	Material costs (Baht)		Delivery Distance (Km.)	Truck	Delivery costs (Baht)		Total costs (Baht)
			Unit price	Unit			Delivery costs (Baht)	Loading costs (Baht)	Material costs + Delivery costs
1.	Cushed stone	–	220.00	m³	38	10 w.	105.00	–	325.00
2.	Cusher dust	–	–	m³	–	10 w.	–	–	–
3.	Gravel 3/4"	–	–	m³	–	10 w.	–	–	–
4.	Gravel 1/2"	–	–	m³	–	10 w.	–	–	–
5.	Gravel 3/8"	–	–	m³	–	10 w.	–	–	–
6.	Aggregate	–	310.00	m³	38	10 w.	105.00	–	415.00
7.	Laterite	–	–	m³	–	10 w.	–	–	–
8.	Asphalt AC60–70	Sriracha Chonburi	15,725.00	Ton	1,114	Trailer	1,425.79	35	17,185.79
9.	Asphalt CSS–1	Bangkok	12,800.00	Ton	985	Trailer	1,260.67	25	14,085.67
10.	Asphalt CRS–2	Bangkok	11,725.00	Ton	985	Trailer	1,260.67	25	13,010.67
11.	Portland cement	–	2,194.00	Ton	234	Trailer	299.39	50	2,543.39

Source: Bureau of Administrative Maintenance Department of Highways.

Remarks: Asphalt and cement prices used prices at November 2007

Total costs estimation of pavement in-place recycling of DOH in example project has details as following:

Direct costs of pavement in-place recycling

Data for estimation:

Weather condition	=	Rainy
Average Zola fuel prices	=	29.50 Baht/liter
Recycling depth	=	20 hours
Specific weight of RAP	=	2,300 Kg/m^3
Amount of cement	=	4.00 % by RAP weight
Amount of cement/m^2 (S)	=	0.0184 Ton/m^2 (Table 3.1)
Cement costs + Delivery costs (C)	=	2,543.39 Baht/Ton
Traffic Factor (F1)	=	1.013

Machine operation costs + Depreciation costs

$$= \quad 29.29 + 16.76 \ \text{Baht/m}^2$$

$$= \quad 46.05 \ \text{Baht/m}^2$$

Pavement in-place recycling formula from equation 3.1:

$$N = \text{F1} \ [(\text{Machine operation costs} + \text{Depreciation costs}) + AY + SC]$$

$$= [46.05 + (0.0184 \times 2,543.39)]$$

$$= 92.83$$

Direct costs of pavement in-place recycling =   92.83 Baht/m^2

The direct costs of pavement in-place recycling are 92.83 Baht/m^2. The quantity of pavement in-place recycling work in this example project of DOH has 26,385 m^2. So, direct costs (price) is 92.83 × 26,384 = 2,449,226.72 Baht. Sum of direct costs (price) of all work lists is 15,392,121.76 Baht. From sum of direct costs (price) can use to find Factor F from Factor F tables as following:

Finding Factor F

Factor F for road construction in case of advance payment 15.0%, retention money 10.0%, interest rate 7.0%, VAT 7%, and in case rainy1 can be found from Table B.12 in Appendix B.

Direct costs of project = 10,000,000.00 Baht   Factor F (rainy1) = 1.3106

Direct costs of project = 20,000,000.00 Baht   Factor F (rainy1) = 1.2639

Direct costs of example project are 15,392,121.76 Baht, so we can calculate Factor F as follows:

$$\text{Factor F} = 1.3106 - \frac{[(1.3106-1.2639) \times (15,392,121.76-10,000,000.00)]}{(20,000,000.00-10,000,000.00)}$$

$$= 1.2854$$

Taking Factor F multiply with direct costs (unit cost) of each road construction works will get total costs (unit cost) of works as shown in Table 3.10. We can find that total costs (unit cost) of pavement in-place recycling are 119.32 Baht/m^2. Taking total costs (unit cost) of each works multiply with quantity of their works will get total costs (price) of each work. Sum total costs (price) of all works will get project costs that are equal to 19,800,000.00 Baht.

Result of total costs estimation in pavement in-place recycling in the example project of DOH

Table 3.10 Total costs estimation in the example project of DOH

No.	Work List	Quantity	Unit	Direct costs (Baht) Unit cost	Direct costs (Baht) Price	Factor F	Total costs (Baht) Unit cost	Total costs (Baht) Price	Defining Total costs (Baht) Unit cost	Defining Total costs (Baht) Price
1.	Pavement in-place recycling	26,384	m^2	92.83	2,449,226.72	1.2854	119.32	3,148,236.03	119.00	3,139,696.00
2.	Adjust leveling	1,319	m^3	325.00	428,675.00	1.2854	417.76	551,018.85	417.00	550,023.00
3.	Prime coat	26,384	m^2	20.60	543,510.40	1.2854	26.48	698,628.27	26.40	696,537.60
4.	Tack coat	28,192	m^2	10.17	286,797.22	1.2854	13.07	368,540.43	13.00	366,496.00
5.	Asphaltic concrete on prime coat	26,384	m^2	206.75	5,454,892.00	1.2854	265.76	7,011,718.18	265.00	6,991,760.00
6.	Asphaltic concrete on tack coat	28,192	m^2	203.76	5,744,401.92	1.2854	261.91	7,383,854.23	261.00	7,358,112.00
7.	Rod stud	331	unit	240.00	240.00	–	240.00	79,440.00	240.00	79,440.00
8.	Traffic lines	1,909	m^2	251.50	480,113.50	1.2854	323.28	617,137.89	323.00	616,607.00
9.	Traffic management	1	unit	–	4,265.00	–	4,265.00	4,265.00	4,265.00	4,265.00
	Sum direct costs				15,392,121.76		Sum total costs	19,862,838.88		19,802,936.60
								Adjust price		– 2,936.60
								Project costs		19,800,000.00

Source: Bureau of Administrative Maintenance Department of Highways.

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3.1.2 Analysis Factors Affecting Total Costs of Pavement In-Place Recycling in the Example Project of DOH

Total costs of pavement in-place recycling in the example project of DOH from Table 3.10 that are 119.32 Baht/m^2 can be divided into 2 parts that are comprised of direct costs and operation costs.

Direct costs of pavement in-place recycling that are 92.83 Baht/m^2 can find from equation 3.1 that consist of 4 costs: traffic factor value, machine operation costs, depreciation costs, and cement costs. Each costs can be found as follows:

1) Traffic factor uses 1.013 for traffic that is more than 1,000 Vehicles/day.

2) Machine operation costs can be found from Table A.1 in Appendix A. In case fuel prices 29.50 Baht/liter and recycling depth 20 cm, machine operation costs are equal to 29.29 Baht/m^2.

3) Depreciation costs can be found from Table A.1 in Appendix A. In case fuel prices 29.50 Baht/liter, recycling depth 20 cm. and rainy case, depreciation costs are equal to 16.76 Baht/m^2.

4) Cement costs is 46.78 Baht/m^2 depending on 2 factors: amount of cement and cement prices.

Operation costs of pavement in-place recycling can be found from calculation of Factor F that is 1.2854 with direct costs that is 92.83 Baht/m^2. Operation costs are equal to $[92.83 \times (1.2854 - 1)] = 26.49$ Baht/m^2.

Machine operation costs that are 29.29 Baht/m^2 consist of 3 costs: fixed costs, running costs, and labor costs. Defining operating rate is 2,520 m^2/day, Each costs can be found as follows:

1) Fixed costs that are 23.46 Baht/m^2 consist of 4 costs: investment costs, tire costs, maintenance costs, and operator costs.

2) Running costs that are 5.23 Baht/m^2 in case fuel price 29.50 Baht/liter and operating hour 3.5 hours/day consist of 2 costs: fuel costs 4.55 Baht/m^2 and lubricant costs 0.68 Baht/m^2.

3) Labor costs depend on 2 factors: minimum daily wage and numbers of laborer. In example project of DOH, daily minimum daily wage is 149.36 Baht/day and numbers of laborer is 10. So, labor costs are 1,493.60 Baht/day or 0.60 Baht/m².

Fixed costs that are 23.46 Baht/m² in case working hours 8 hours/day consist of 4 costs: investment costs, tire costs, maintenance costs, and operator costs. Each costs can be found as follows:

1) Investment costs that are 1,480.88 Baht/hour or 11,847.04 Baht/day or 4.70 Baht/m² depend on 5 factors: new machine prices 59,631,133.00 Baht, useful life in Table 3.5, interest rate 7%, insurance rate 3%, and working hours 2,000 hours/year.

2) Tire costs that are 88.67 Baht/hour or 709.36 Baht/day or 0.28 Baht/m² depend on 2 factors: tire prices 116,685.00 Baht and tire life in Table 3.5.

3) Maintenance costs that are 5,572.40 Baht/hour or 44,579.20 Baht/day or 17.69 Baht/m² depend on 2 factors: Repair factor in Table 3.6 and new machine prices 59,631,133.00 Baht.

4) Operator costs that are 247.41 Baht/hour or 1,979.28 Baht/day or 0.79 Baht/m² depend on type of machines in Table 3.6

Depreciation costs that are 42,231.80 Baht/day or 16.76 Baht/m² depend on 3 factors: new machine prices 59,631,133.00 Baht, machine life in Table 3.5, and salvage value 5,963,113.30 Baht

Cement costs that are 46.78 Baht/m² depend on 2 factors: quantity of cement and cement prices. Each factor can find as follows:

1) Amount of cement that is 0.0184 Ton/m² can be found from Table 3.1. The example project of DOH defines amount of cement 4% by RAP weight, specific weight of RAP 2,300 Kg/m³, and recycling depth 20 cm.

2) Cement prices that are 2,543.39 Baht/Ton depends on 3 factors: factory prices 2,194.00 Baht/Ton, delivery costs 299.39 Baht/Ton, and loading costs 50.00 Baht/Ton. Delivery costs for fuel prices 29.50 Bath/liter and delivery distance 234 km. can be found from Table A.3 in Appendix A.

Operation costs that are calculated from Factor F in Table 3.11 consist of 4 costs: administrative costs 13.1978%, interest costs 1.4348%, profit 5.50%, and VAT 1.2854 − 1.2013 = 0.0841 or 8.41%.

Administrative costs that are 13.1978% of direct costs as shown in Table 3.11 consist of 5 costs: contracting costs 0.7186%, site office and vehicles cost 5.0480%, staff and headquarter 5.6798%, risk costs 0.9250%, and addition administrative costs 0.8264%. Each costs can be found as follows:

1) Contracting costs that are 0.7186% of direct costs consist of 4 costs: performance bond fee 0.1106%, guarantee bond fee 0.25%, stamp duty 0.10%, and compensation fund and social insurance fund 0.2580%.

2) Site office and vehicles costs that are 5.0480% of direct costs consist of 2 costs: site office cost 14,500 Baht/month or 1.0705% and vehicles costs 53,880 Baht/month or 3.9775%.

3) Staff and headquarter costs that are 5.6798% of direct costs consist of 2 costs: staff costs 55,000 Baht/month or 4.1684% and headquarter costs 20,500 Baht/month or 1.5114%.

4) Risks costs that are 0.9250% of direct costs consist of 3 costs: insurance costs 0.25%, other risks costs 0.05%, and addition risks costs 0.6250%.

5) Addition administrative costs are 0.8264% of direct costs.

Table 3.11 Operation costs and Factor F in rainy case in the example project of DOH

| Advance payment | 15% | | Interest rate | | | | 7% |
| Retention money | 10% | | VAT | | | | 7% |

| Direct costs (Baht) | Operation costs (rainy1) (%) | | | | Factor | VAT | Factor F (rainy1) |
	Administrative costs	Interest costs	Profit	Total			
10,000,000.00	15.5275	1.4584	5.5000	22.4859	1.2248	1.07	1.3106
15,392,121.76	13.1978	1.4348	5.5000	20.1326	1.2013	1.07	1.2854
20,000,000.00	11.2068	1.4147	5.5000	18.1215	1.1812	1.07	1.2639

Operation costs can be calculated in unit cost as follows: $[92.83 \times (1.2854 - 1)] = 26.49$ Baht/m^2. The operation costs consists of 4 costs: administrative costs $[92.83 \times (13.1978/100)] = 12.25$ Baht/m^2, interest costs $[92.83 \times (1.4348/100)] = 1.33$ Baht/m^2, profit $[92.83 \times (5.5/100)] = 5.10$ Baht/m^2, and VAT $[92.83 \times (1.2854 - 1.2013)] = 7.81$ Baht/m^2.

Administrative costs that are 12.25 Baht/m^2 consist of 5 costs: contracting costs $[92.83 \times (0.7186/100)] = 0.67$ Baht/m^2, site office and vehicles costs $[92.83 \times (5.0480/100)] = 4.69$ Baht/m^2, staff and headquarter costs $[92.83 \times (5.6798/100)] = 5.27$ Baht/m^2, risks costs $[92.83 \times (0.9250/100)] = 0.86$ Baht/m^2, and addition administrative costs $[92.83 \times (0.8264/100)] = 0.76$ Baht/m^2. Each costs can be found as follows:

1) Contracting costs that are 0.67 Baht/m^2 consist of 4 costs: performance bond fee $[92.83 \times (0.1106/100)] = 0.10$ Baht/m^2, guarantee bond fee $[92.83 \times (0.25/100)] = 0.23$ Baht/m^2, stamp duty $[92.83 \times (0.1/100)] = 0.10$ Baht/m^2, and compensation fund and social insurance fund $[92.83 \times (0.2580/100)] = 0.24$ Baht/m^2.

2) Site office and vehicles costs that are 5.27 Baht/m^2 consist of 2 costs: site office costs $[92.83 \times (1.0705/100)] = 1.00$ Baht/m^2 and vehicles costs $[92.83 \times (3.9775/100)] = 3.69$ Baht/m^2.

3) Staff and headquarter costs that are 5.27 Baht/m^2 consist of 2 costs: staff costs $[92.83 \times (4.1684/100)] = 3.87$ Baht/m^2 and headquarter costs $[92.83 \times (1.5114/100)] = 1.40$ Baht/m^2.

4) Risks costs that are 0.86 Baht/m^2 consist of 3 costs: insurance costs $[92.83 \times (0.25/100)] = 0.23$ Baht/m^2, other risks costs $[92.83 \times (0.05/100)] = 0.05$ Baht/m^2, and addition risks costs $[92.83 \times (0.6250/100)] = 0.58$ Baht/m^2.

5) Addition administrative costs are 0.76 Baht/m^2.

3.1.3 Total Costs Structure of Pavement In-Place Recycling in the Example Project of DOH

The result of analysis of factors affecting total costs of pavement in-place recycling in the example project of DOH in 3.1.2 can be shown in the proportion of costs in total costs structure as following:

The proportion of costs in total costs of pavement in-place recycling in the example project of DOH can be shown in Figure 3.4. Total costs that are 119.32 Baht/m^2 are comprised of direct costs 26.49 Baht/m^2 and operation costs 26.49 Baht/m^2. The largest proportion of costs in total costs is direct costs 78% and then operation costs 22% respectively.

The proportion of costs in direct costs of pavement in-place recycling in the example project of DOH can be shown in Figure 3.5. Direct costs that are 92.83 Baht/m^2 consist of 3 costs: machine operation costs 29.29 Baht/m^2, depreciation costs 16.76 Baht/m^2, and cement costs 46.78 Baht/m^2. The largest proportion of costs in direct costs is cement costs 50% and then machine operation costs 32% and depreciation costs 18% respectively.

The proportion of costs in operation costs of pavement in-place recycling in the example project of DOH can be shown in Figure 3.6. Operation costs that are 26.49 Baht/m^2 consist of 4 costs: administrative costs 12.25 Baht/m^2, interest costs 1.33 Baht/m^2, profit 5.1 Baht/m^2, and VAT 7.81 Baht/m^2. The largest proportion of costs in operation costs is administrative costs 47% and then VAT 29%, profit 19%, and interest costs 5% respectively.

All components of costs affecting direct costs of pavement in-place recycling can be added in Figure 3.5 to show the proportion of all costs in direct costs of pavement in-place recycling in the example project of DOH as shown in Figure 3.7. Direct costs that are 92.83 Baht/m^2 consist of 9 costs: investment costs 4.70 Baht/m^2, tire cost 0.28 Baht/m^2, maintenance costs 17.69 Baht/m^2, operator costs 0.79 Baht/m^2, fuel costs 4.55 Baht/m^2, lubricant costs 0.68 Baht/m^2, labor costs 0.60 Baht/m^2, depreciation costs 16.76 Baht/m^2, and cement costs 46.78 Baht/m^2.
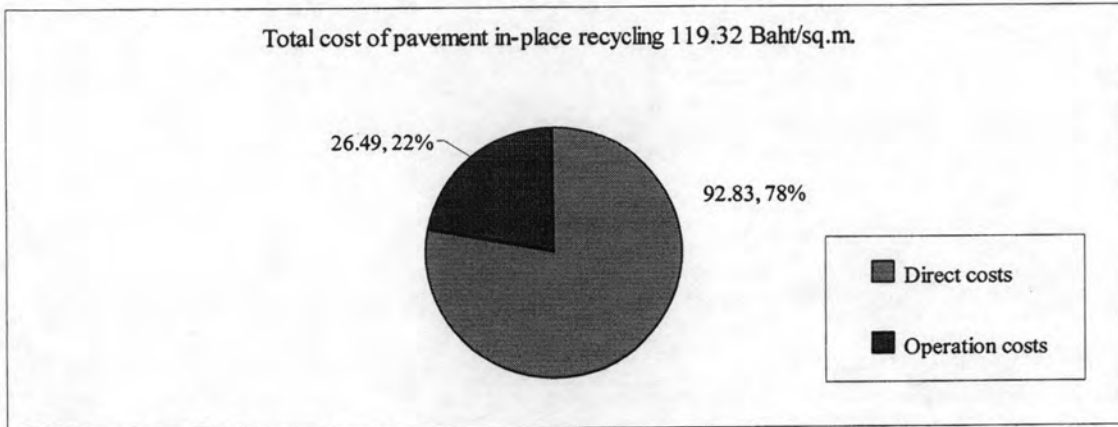
Total cost of pavement in-place recycling 119.32 Baht/sq.m.

26.49, 22%

92.83, 78%

Direct costs

Operation costs

Figure 3.4 Proportion of costs in total costs of pavement in-place recycling in the example project of DOH

Direct costs 92.83 Baht/sq.m.
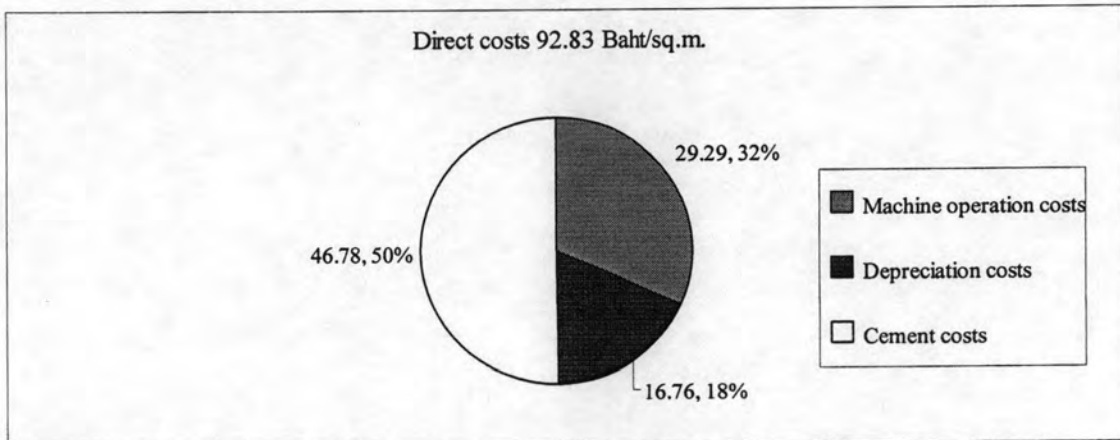
29.29, 32%

46.78, 50%

16.76, 18%

Machine operation costs

Depreciation costs

Cement costs

Figure 3.5 Proportion of costs in direct costs of pavement in-place recycling in the example project of DOH

Operation costs 26.49 Baht/sq.m.

7.81, 29%

12.25, 47%

5.1, 19%

1.33, 5%

Administrative costs

Interest cost

Profit

VAT
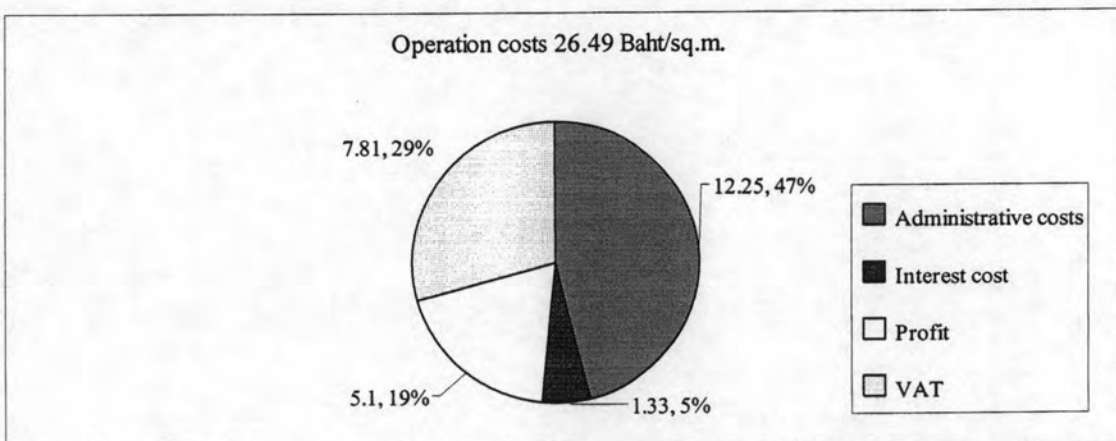
Figure 3.6 Proportion of costs in operation costs of pavement in-place recycling in the example project of DOH

From Figure 3.7, the largest proportion of costs in direct costs is cement costs 50% and then maintenance costs 19%, depreciation costs 18%, investment costs 5%, fuel costs 5%, operator costs 1%, lubricant costs 1%, labor costs 1%, and tire costs less than 1% respectively.

All components of costs affecting operation costs of pavement in-place recycling can be added in Figure 3.6 to show the proportion of all costs in operation costs of pavement in-place recycling in the example project of DOH as shown in Figure 3.8. Operation costs that are 26.49 Baht/m^2 consist of 11 costs: contracting costs 0.67 Baht/m^2, site office costs 1.00 Baht/m^2, vehicles costs 3.69 Baht/m^2, staff costs 3.87 Baht/m^2, headquarter costs 1.40 Baht/m^2, risks costs 0.86 Baht/m^2, addition administrative costs 0.76 Baht/m^2, interest costs 0.79 Baht/m^2, addition interest costs 0.54 Baht/m^2, profit 5.10 Baht/m^2, and VAT 7.81 Baht/m^2.

From Figure 3.8, The largest proportion of costs in operation costs is VAT 29% and then profit 19%, staff costs 15%, vehicles costs 14%, headquarter costs 5%, site office costs 4%, risks costs 3%, interest costs 3%, addition administrative costs 3%, contracting costs 3%, and addition interest costs 2% respectively.

All costs affecting direct costs in Figure 3.7 and all costs affecting operation costs in Figure 3.8 can be combined to show the proportion of all costs in total costs of pavement in-place recycling in the example project of DOH as shown in Figure 3.9. Total costs that are 119.32 Baht/m^2 consist of 20 costs: investment costs 4.70 Baht/m^2, tire cost 0.28 Baht/m^2, maintenance costs 17.69 Baht/m^2, operator costs 0.79 Baht/m^2, fuel costs 4.55 Baht/m^2, lubricant costs 0.68 Baht/m^2, labor costs 0.60 Baht/m^2, depreciation costs 16.76 Baht/m^2, and cement costs 46.78 Baht/m^2, contracting costs 0.67 Baht/m^2, site office costs 1.00 Baht/m^2, vehicles costs 3.69 Baht/m^2, staff costs 3.87 Baht/m^2, headquarter costs 1.40 Baht/m^2, risks costs 0.86 Baht/m^2, addition administrative costs 0.76 Baht/m^2, interest costs 0.79 Baht/m^2, addition interest costs 0.54 Baht/m^2, profit 5.10 Baht/m^2, and VAT 7.81 Baht/m^2.

Direct costs 92.83 Baht/sq.m.

4.70, 5%

0.28, <1%

17.69, 19%

0.79, 1%

4.55, 5%

0.68, 1%

0.60, 1%

46.78, 50%

16.76, 18%

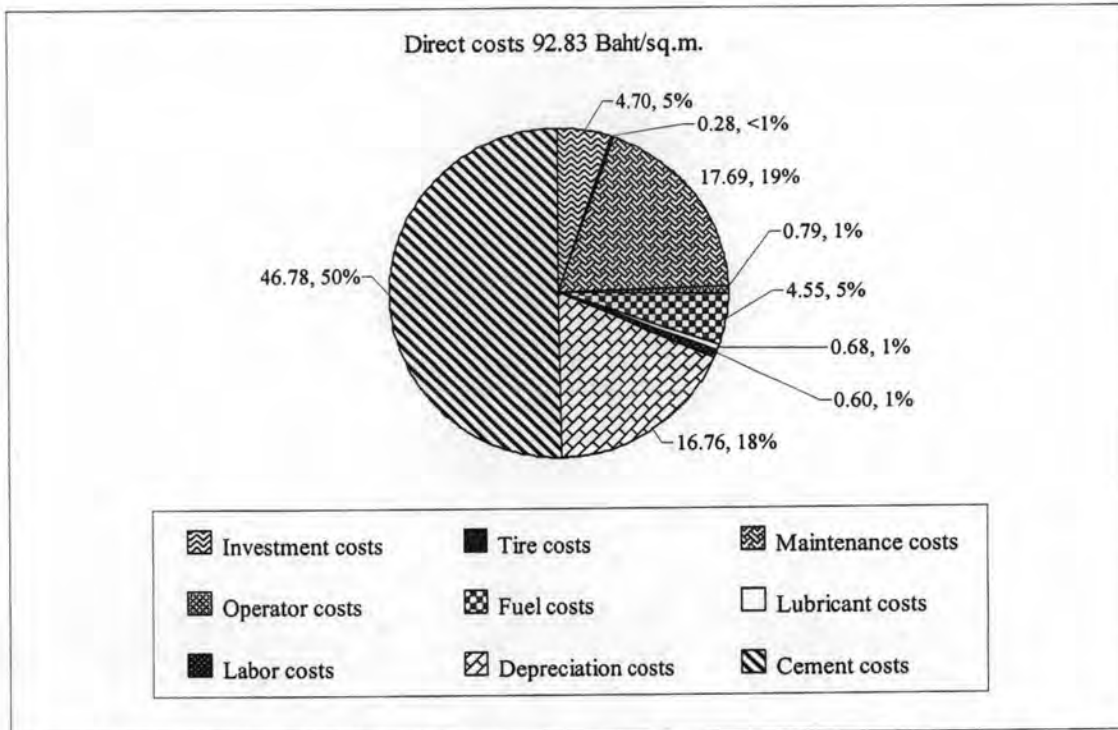| ▨ Investment costs | ■ Tire costs | ▨ Maintenance costs |
| ▨ Operator costs | ▨ Fuel costs | ☐ Lubricant costs |
| ■ Labor costs | ▨ Depreciation costs | ⊠ Cement costs |

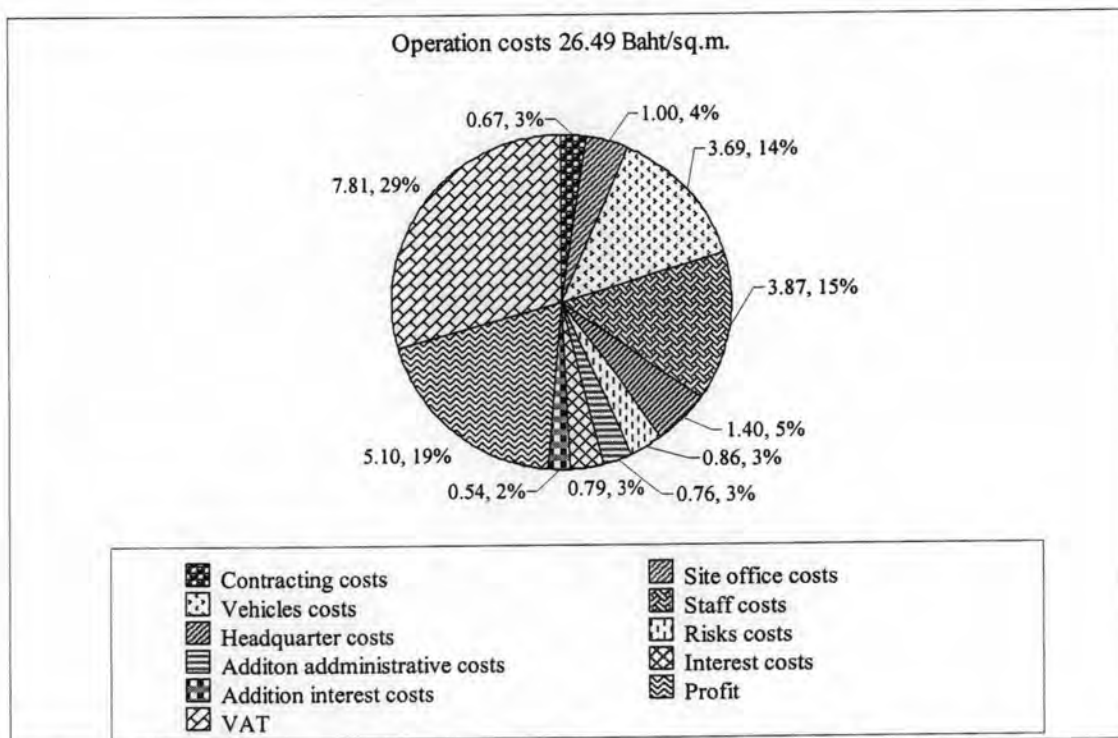Figure 3.7 Proportion of all costs in direct costs of pavement in-place recycling in the example project of DOH

Operation costs 26.49 Baht/sq.m.

0.67, 3%

1.00, 4%

3.69, 14%

7.81, 29%

3.87, 15%

5.10, 19%

1.40, 5%

0.86, 3%

0.54, 2%

0.79, 3%

0.76, 3%

▨ Contracting costs	▨ Site office costs
▨ Vehicles costs	▨ Staff costs
▨ Headquarter costs	▨ Risks costs
▤ Additon addministrative costs	⊠ Interest costs
▨ Addition interest costs	▨ Profit
⊠ VAT	

Figure 3.8 Proportion of all costs in operation costs of pavement in-place recycling in the example project of DOH

Total costs of Pavement in-place recycling 119.32 Baht/sq.m.

5.10, 4% 7.81, 7% 4.70, 4%
0.79, 1% 0.54, <1% 0.28, <1% 17.69, 15%
0.76, 1% 0.79, 1%
0.86, 1% 4.55, 4%
1.40, 1% 0.68, 1%
3.87, 3% 0.60, 1%
3.69, 3%
1.00, 1% 16.76, 14%
0.67, 1%

46.78, 39%

▨ Investment costs   ■ Tire costs
▧ Maintenance costs   ▨ Operator costs
⊞ Fuel costs   ■ Lubricant costs
☐ Labor costs   ▨ Depreciation costs
▨ Cement costs   ■ Contracting costs
▦ Site office costs   ▨ Vehicles costs
▨ Staff costs   ▨ Headquarter costs
■ Risks costs   ■ Additon addministrative costs
■ Interest costs   ☐ Addition interest costs
▨ Profit   ☰ VAT

Figure 3.9 Total costs structure of pavement in-place recycling in the example project
of DOH

From Figure 3.9, the largest proportion of costs in total cost is cement
cost 39% and then maintenance costs 15%, depreciation costs 14%, VAT 7%, profit
4%, investment costs 4%, fuel costs 4%, staff costs 3%, vehicles costs 3%,
headquarter costs 1%, site office costs 1%, risks cost 1%, operator cost 1%, interest
costs 1%, addition administrative costs 1%, lubricant costs 1%, contracting costs 1%,
labor costs 1%, addition interest costs less than 1%, and tire costs less than 1%
respectively.

3.1.4 Total Costs Estimation in Pavement In-Place Recycling in the Example Project of DOR

Total costs estimation in pavement in-place recycling of DOR can be shown by defining the example project as following:

Example project:

Owner: Bureau of Maintenance and Traffic Safety Department of Rural Roads.

Type of work: Pavement In-Place Recycling

Start date: 22 August 2007

Job detail:

Work code: 4012

Junction part: Highways 1020 – Nong Sao

Location: Theng, Phayamengrai district, Chiang Rai province

Repair distance: 4.512 km.

Range: km. 8+000 to km. 10+300 and km. 14+100 to km. 16+312

Original pavement: Asphaltic concrete width 6.00 m.

Weather condition: Normal rain

Average Zola fuel prices: 25.50 Baht/liter

Advance payment: 15.0 %

Retention money: 0 %

Interest rate: 7.0 %

VAT: 7.0 %

Material Prices and Delivery Costs

Table 3.12 Material prices and delivery costs in the example project of DOR

No.	Item	Source	Material costs (Baht)		Delivery Distance (Km.)	Truck	Delivery costs (Baht)		Total costs (Baht)
			Unit price	Unit			Delivery costs (Baht)	Loading costs (Baht)	Material costs + Delivery costs
1.	Cushed stone	Chiang Rai	275.00	m³	27	10 w.	69.40	–	344.40
2.	Cusher dust	Chiang Rai	275.00	m³	27	10 w.	69.40	–	344.40
3.	Gravel 3/4"	Chiang Rai	295.00	m³	27	10 w.	69.40	–	364.40
4.	Gravel 1/2"	Chiang Rai	327.00	m³	27	10 w.	69.40	–	396.40
5.	Gravel 3/8"	Chiang Rai	275.00	m³	27	10 w.	69.40	–	344.40
6.	Aggregate	Chiang Rai	285.20	m³	27	10 w.	69.40	–	354.60
7.	Laterite	Chiang Rai	25.00	m³	20	10 w.	51.67	–	76.67
8.	Asphalt AC60–70	Sriracha Chonburi	14,700.00	Ton	825	Trailer	972.81	–	15,672.81
9.	Asphalt CSS–1	Bangkok	12,400.00	Ton	825	Trailer	972.81	–	13,372.81
10.	Asphalt CRS–2	Bangkok	11,250.00	Ton	825	Trailer	972.81	–	12,222.81
11.	Portland cement	Chiang Rai	2,300.00	Ton	35	Trailer	41.48	–	2,341.48

Source: Bureau of Maintenance and Traffic Safety Department of Rural Roads.

Total costs estimation of pavement in-place recycling of DOR in example project has details as following:

Direct costs of pavement in-place recycling

Data for estimation:

Weather condition	=	Normal Rain
Average Zola fuel prices	=	25.50 Baht/liter
Recycling depth	=	20 hours
Specific weight of RAP	=	2,200 Kg/m^3
Amount of cement	=	3.50 % by RAP weight
Amount of cement/m^2 (S)	=	0.015 Ton/m^2 (Table 3.2)
Cement costs + Delivery costs (C)	=	2,341.48 Baht/Ton
Traffic Factor (F1)	=	1.013

Machine operation costs + Depreciation costs

$$= \quad 28.58 + 13.41 \ \text{Baht/m}^2$$

$$= \quad 41.98 \ \text{Baht/m}^2$$

Pavement in-place recycling formula from equation 3.1:

N = F1 [(Machine operation costs + Depreciation costs) + AY + SC]

$$= \quad 1.013 \times [41.98 + (0.015 \times 2{,}341.48)]$$

$$= \quad 78.04$$

Direct costs of pavement in-place recycling =   78.04 Baht/m^2

Bill of quantity for direct costs estimation

Table 3.13 Bill of quantity for direct costs in an example project of DOR

No.	Work list	Quantity	Unit	Costs (Baht)			Direct costs (Baht)
				Material	Labor	Total	
1	Pavement structure						
	1.1 Pavement in-place recycling	21,420	m²	–	–	78.04	1,671,597.17
	1.2 Benching	–	m³	–	–	–	–
	1.3 Cut	–	m³	–	–	–	–
	1.4 Clay embankment	–	m³	–	–	–	–
	1.5 Sand embankment	–	m³	–	–	–	–
	1.6 Subbase	–	m³	–	–	–	–
	1.7 Adjusted leveling	643	m³	516.60	65.01	581.61	373,743.98
	1.8 Compact	–	m³	–	–	–	–
	1.9 Skin Patch	–	m²	–	–	–	–
	1.10 Deep Patch	800	m²	–	–	165.46	132,368.00
2	Surface						
	2.1 Prime Coat	16,065	m²	10.70	5.87	16.57	266,198.04
	2.2 Tack Coat	10,908	m²	2.44	5.60	8.04	87,700.32
	2.3 Asphaltic Concrete						
	- on Prime Coat	16,065	m²	142.96	11.24	154.20	2,477,232.25
	- on Tack Coat	10,908	m²	142.96	8.85	151.81	1,655,943.48
3	Shoulder						
	3.1 Prime Coat	5,302	m²	10.70	5.87	16.57	87,854.14
	3.2 Tack Coat	3,600	m²	2.44	5.60	8.04	28,944.00
	3.3 Asphaltic Concrete						
	- on Prime Coat	5,302	m²	142.96	11.24	154.20	817,568.40
	- on Tack Coat	3,600	m²	142.96	8.85	151.81	546,516.00
	3.4 Laterite	–	m³	–	–	–	–
4	Traffic lines						
	4.1 Thermoplastic	1,231	m²	226.00	20.00	246.00	302,826.00
5	Traffic marks	1	set	–	–	–	425,956.00
	Total						8,874,447.79

Source: Bureau of Maintenance and Traffic Safety Department of Rural Roads.

The direct costs of pavement in-place recycling are 78.04 Baht/m^2. The quantity of pavement in-place recycling work in this example project of DOH has 21,420 m^2. So, direct costs (price) is 8.04 × 21,420 = 1,671,597.17 Baht. Sum of direct costs (price) of all work lists is 8,874,447.79 Baht. From sum of direct costs (price) can use to find Factor F from Factor F tables as following:

Finding Factor F

Factor F for road construction in case of advance payment 15.0%, retention money 0%, interest rate 7.0%, VAT 7%, and in case normal rain can be found from Table B.4 in Appendix B.

Direct costs of project = 5,000,000.00 Baht   Factor F (normal) = 1.3322

Direct costs of project = 10,000,000.00 Baht   Factor F (normal) = 1.2860

Direct costs of example project is 8,874,447.79 Baht, so we can calculate Factor F as follows:

$$\text{Factor F} = 1.3322 - \frac{[(1.3322-1.2860) \times (8,874,447.79-5,000,000.00)]}{(10,000,000.00-5,000,000.00)}$$

$$= 1.2964$$

Taking Factor F multiply with direct costs (unit cost) of each road construction works will get total costs (unit cost) of works as shown in Table 3.14. We can find that total costs (unit cost) of pavement in-place recycling are 101.17 Baht/m^2. Taking total costs (unit cost) of each works multiply with quantity of their works will get total costs (price) of each work. Sum total costs (price) of all works will get project costs that are equal to 11,500,000.00 Baht.

Result of total costs estimation in pavement in-place recycling in the example project of DOR

Table 3.14 Total costs estimation in the example project of DOR

No.	Work List	Quantity	Unit	Direct costs (Baht)		Factor F	Total costs (Baht)		Defining Total costs (Baht)	
				Unit cost	Price		Unit cost	Price	Unit cost	Price
1.	Pavement in-place recycling	21,420	m²	78.04	1,671,597.17	1.2964	101.17	2,167,058.57	101.17	2,167,058.57
2.	Adjust leveling	643	m³	581.61	373,743.98	1.2964	754.00	484,521.70	754.00	484,521.70
3.	Deep Patch	800	m²	165.46	132,368.00	1.2964	214.50	171,601.88	214.50	171,601.88
4.	Prime coat	21,367	m²	16.57	354,052.18	1.2964	21.48	458,993.25	21.48	458,993.25
5.	Tack coat	14,508	m²	8.04	116,644.32	1.2964	10.42	151,217.70	10.42	151,217.70
6.	Asphaltic concrete on prime coat	21,367	m²	154.20	3,294,800.65	1.2964	199.90	4,271,379.56	199.90	4,271,379.56
7.	Asphaltic concrete on tack coat	14,508	m²	151.81	2,202,459.48	1.2964	196.81	2,855,268.47	196.81	2,855,268.47
8.	Traffic lines	1,231	m²	246.00	302,826.00	1.2964	318.91	392,583.63	318.91	392,583.63
9.	Traffic markings	1	unit	425,956.00	425,956.00	1.2964	552,209.36	552,209.36	552,209.36	552,209.36
	Sum direct costs				8,874,447.79		Sum total costs	11,504,834.10		11,504,834.10
									Adjust price	−4,834.10
									Project costs	11,500,000.00

Source: Bureau of Maintenance and Traffic Safety Department of Rural Roads.

3.1.5 Analysis Factors Affecting Total Cost of Pavement In-Place Recycling in the Example Project of DOR

Total costs of pavement in-place recycling in example project of DOR from Table 3.14 that is 101.17 Baht/m^2 can be divided into 2 parts that are comprised of direct costs and operation costs.

Direct costs of pavement in-place recycling that are 78.04 Baht/m^2 can be found from equation 3.1 that consist of 4 costs: traffic factor value, machine operation costs, depreciation costs, and cement costs. Each costs can find as follows:

1) Traffic Factor use 1.013 for traffic that is more than 1,000 Vehicles/day.

2) Machine operation costs can be found from Table A.1 in Appendix A. In case fuel prices 25.50 Baht/liter and recycling depth 20 cm, machine operation costs are equal to 28.58 Baht/m^2.

3) Depreciation costs can be found from Table A.1 in Appendix A. In case fuel prices 25.50 Baht/liter, recycling depth 20 cm, normal rain case, depreciation costs are equal to 13.41 Baht/m^2.

4) Cement costs are 35.12 Baht/m^2 depending on 2 factors: amount of cement and cement prices.

Operation costs of pavement in-place recycling can be found from calculation of Factor F that is 1.2964 with direct costs that is 78.04 Baht/m^2. Operation costs are equal to $[78.04 \times (1.2964 - 1)] = 23.13$ Baht/m^2.

Machine operation costs that are 28.58 Baht/m^2 consist of 3 costs: fixed costs, running costs, and labor costs. Defining operating rate is 2,520 m^2/day, Each costs can be found as follows:

1) Fixed costs that are 23.46 Baht/m^2 consist of 4 costs: investment costs, tire costs, maintenance costs, and operator costs.

2) Running costs that are 4.52 Baht/m^2 in case fuel price 25.50 Baht/liter and operating hour 3.5 hours/day consist of 2 costs: fuel costs 3.93 Baht/m^2 and lubricant costs 0.59 Baht/m^2.

3) Labor costs depend on 2 factors: minimum daily wage and numbers of laborer. In example project of DOR, minimum daily wage is 149.36 Baht/day and numbers of laborer is 10. So, labor costs are 1,493.60 Baht/day or 0.60 Baht/m^2.

Fixed costs that are 23.46 Baht/m^2 in case working hours 8 hours/day consist of 4 costs: investment costs, tire costs, maintenance costs, and operator costs. Each costs can be found as follows:

1) Investment costs that are 1,480.88 Baht/hour or 11,847.04 Baht/day or 4.70 Baht/m^2 depend on 5 factors: new machine prices 59,631,133.00 Baht, useful life in Table 3.5, interest rate 7%, insurance rate 3%, and working hours 2,000 hours/year.

2) Tire costs that are 88.67 Baht/hour or 709.36 Baht/day or 0.28 Baht/m^2 depend on 2 factors: tire prices 116,685.00 Baht and tire life in Table 3.5.

3) Maintenance costs that are 5,572.40 Baht/hour or 44,579.20 Baht/day or 17.69 Baht/m^2 depend on 2 factors: Repair factor in Table 3.6 and new machine prices 59,631,133.00 Baht.

4) Operator costs that are 247.41 Baht/hour or 1,979.28 Baht/day or 0.79 Baht/m^2 depend on type of machines in Table 3.6

Depreciation costs that are 33,785.44 Baht/day or 13.41 Baht/m^2 depend on 3 factors: new machine prices 59,631,133.00 Baht, useful life in Table 3.5, and salvage value 5,963,113.30 Baht

Cement costs that are 35.12 Baht/m^2 depend on 2 factors: amount of cement and cement prices. Each factor can find as follows:

1) Amount of cement that is 0.015 Ton/m^2 can be found from Table 3.2. The example project of DOR defines amount of cement 3.5% by RAP weight, specific weight of RAP 2,200 Kg/m^3, and recycling depth 20 cm.

2) Cement prices that are 2,341.48 Baht/Ton depend on 2 factors: factory prices 2,300.00 Baht/Ton and delivery costs 41.48 Baht/Ton. Delivery costs for fuel price 25.50 Bath/liter and delivery distance 35 km. can be found from Table A.2 in Appendix A.

Operation costs that are calculated from Factor F in Table 3.15 consist of 4 costs: administrative costs 14.9854%, interest costs 0.6712%, profit 5.50%, and VAT 1.2964 − 1.2115 = 0.0849 or 8.50%.

Administrative costs that are 14.9854% of direct costs as shown in Table 3.15 consist of 5 costs: contracting costs 0.6948%, site office and vehicles cost 6.6160%, staff and headquarter 7.3746%, and risks costs 0.3%. Each costs can find as follows:

1) Contracting costs that are 0.6948% of direct costs consists of 4 costs: performance bond fee 0.0868%, guarantee bond fee 0.25%, stamp duty 0.10%, and compensation fund and social insurance fund 0.2580%.

2) Site office and vehicles costs that are 6.6160% of direct costs consist of 2 costs: site office cost 14,500 Baht/month or 1.4029% and vehicles costs 53,880 Baht/month or 5.2131%.

3) Staff and headquarter costs that are 7.3746% of direct costs consist of 2 costs: staff costs 55,000 Baht/month or 5.3926% and headquarter costs 20,500 Baht/month or 1.9820%.

4) Risks costs that are 0.30% of direct costs consist of 3 costs: insurance costs 0.25% and other risks costs 0.05%.

Table 3.15 Operation costs and Factor F in normal rain case in the example project of DOR

| Advance payment | | 15% | | Interest rate | | 7 % |
| Retention money | | 0 % | | VAT | | 7 % |

| Direct costs (Baht) | Operation costs (normal) (%) | | | | Factor | VAT | Factor F |
	Administrative costs	Interest costs	Profit	Total			
≤ 5,000,000.00	18.2361	0.7729	5.5000	24.5090	1.2451	1.07	1.3322
8,874,447.79	14.9854	0.6712	5.5000	21.1566	1.2115	1.07	1.2964
10,000,000.00	14.0410	0.6417	5.5000	20.1826	1.2018	1.07	1.2860

Operation costs can be calculated in unit cost as follows: [78.04 × (1.2964 − 1)] = 23.13 Baht/m². Operation costs consist of 4 costs: administrative costs [78.04 × (14.9854/100)] = 11.69 Baht/m², interest costs [78.04 × (0.6712/100)] = 0.52 Baht/m², profit [78.04 × (5.5/100)] = 4.29 Baht/m² and VAT [78.04 × (1.2964 − 1.2115)] = 6.63 Baht/m².

Administrative costs that are 11.69 Baht/m² consist of 5 costs: contracting costs [78.04 × (0.6948/100)] = 0.54 Baht/m², site office and vehicles costs [78.04 × (6.6160/100)] = 5.16 Baht/m², staff and headquarter costs [78.04 × (7.3746/100)] = 5.76 Baht/m², and risks costs [78.04 × (0.30/100)] = 0.23 Baht/m². Each costs can find as follows:

1) Contracting costs that are 0.54 Baht/m² consist of 4 costs: performance bond fee [78.04 × (0.0868/100)] = 0.07 Baht/m², guarantee bond fee [78.04 × (0.25/100)] = 0.20 Baht/m², stamp duty [78.04 × (0.1/100)] = 0.08 Baht/m², and compensation fund and social insurance fund [78.04 × (0.2580/100)] = 0.20 Baht/m².

2) Site office and vehicles costs that are 5.16 Baht/m² consist of 2 costs: site office costs [78.04 × (1.4029/100)] = 1.09 Baht/m² and vehicles costs [78.04 × (5.2131/100)] = 4.07 Baht/m².

3) Staff and headquarter costs that are 5.76 Baht/m² consist of 2 costs: staff costs [78.04 × (5.3926/100)] = 4.21 Baht/m² and headquarter costs [78.04 × (1.9820/100)] = 1.55 Baht/m².

4) Risks costs that are 0.23 Baht/m² consist of 3 costs: insurance costs [78.04 × (0.25/100)] = 0.20 Baht/m², other risks costs [92.83 × (0.05/100)] = 0.05 Baht/m², and addition risks costs [78.04 × (0.05/100)] = 0.03 Baht/m².

3.1.6 Total Costs Structure of Pavement In-Place Recycling in the Example Project of DOR

The result of analysis of factors affecting total costs of pavement in-place recycling in the example project of DOR in 3.1.5 can be shown in proportion of costs in total costs structure as following:

The proportion of costs in total costs of pavement in-place recycling in the example project of DOR can be shown in Figure 3.10. Total costs that are 101.17 Baht/m^2 are comprised of direct costs 78.04 Baht/m^2 and operation costs 23.13 Baht/m^2. The largest proportion of costs in total costs is direct costs 77% and then operation costs 23% respectively.

The proportion of costs in direct costs of pavement in-place recycling in the example project of DOR can be shown in Figure 3.11. Direct costs that are 78.04 Baht/m^2 consist of 4 costs: machine operation costs 28.58 Baht/m^2, depreciation costs 13.41 Baht/m^2, cement costs 35.12 Baht/m^2, and traffic factor value 0.93 Baht/m^2. The largest proportion of costs in direct costs is cement costs 45% and then machine operation costs 37%, depreciation costs 17%, and traffic factor 1% respectively.

The proportion of costs in operation costs of pavement in-place recycling in the example project of DOR can be shown in Figure 3.12. Operation costs that are 23.13 Baht/m^2 will consist of 4 costs: administrative costs 11.69 Baht/m^2, interest costs 0.52 Baht/m^2, profit 4.29 Baht/m^2, and VAT 6.63 Baht/m^2. The largest proportion of costs in operation costs is administrative costs 50% and then VAT 29%, profit 19%, and interest costs 2% respectively.

All components of costs affecting direct costs of pavement in-place recycling can be added in Figure 3.11 to show the proportion of all costs in direct costs of pavement in-place recycling in the example project of DOR as shown in Figure 3.13. Direct costs that are 78.04 Baht/m^2 consist of 10 costs: investment costs 4.70 Baht/m^2, tire cost 0.28 Baht/m^2, maintenance costs 17.69 Baht/m^2, operator costs 0.79 Baht/m^2, fuel costs 3.93 Baht/m^2, lubricant costs 0.59 Baht/m^2, labor costs 0.60 Baht/m^2, depreciation costs 13.41 Baht/m^2, cement costs 35.12 Baht/m^2, and traffic factor value 0.93 Baht/m^2.
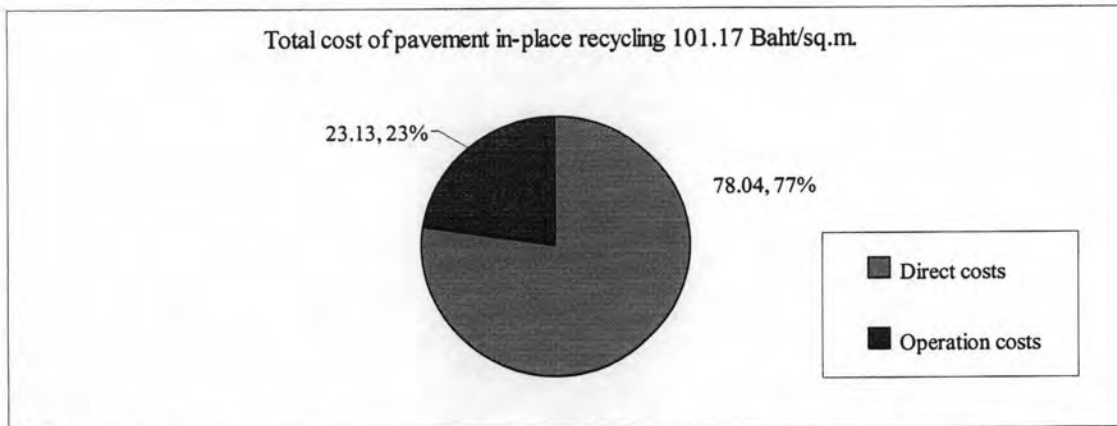
Total cost of pavement in-place recycling 101.17 Baht/sq.m.

23.13, 23%

78.04, 77%

Direct costs

Operation costs

Figure 3.10 Proportion of costs in total costs of pavement in-place recycling in the example project of DOR

Direct costs 78.04 Baht/sq.m.

0.93, 1%

28.58, 37%

35.12, 45%

13.41, 17%

Machine operation costs

Depreciation costs

Cement costs

Traffic factor
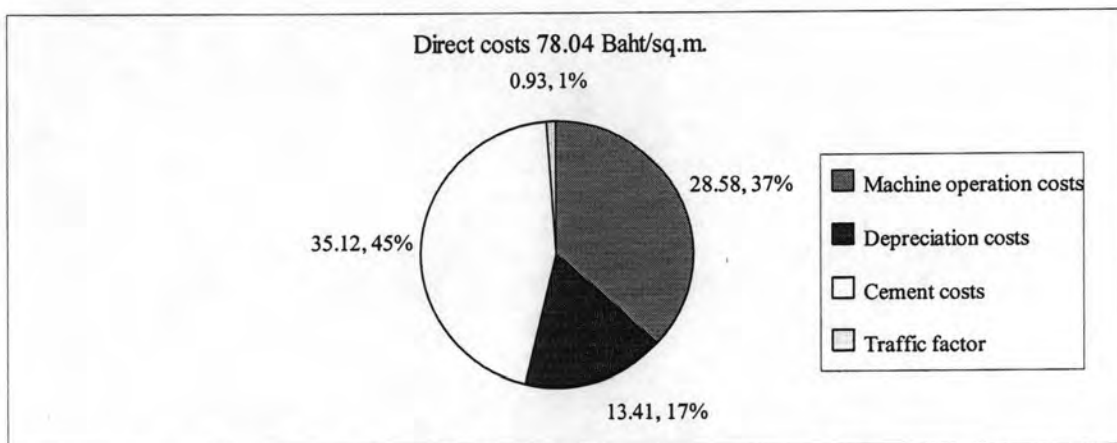
Figure 3.11 Proportion of costs in direct costs of pavement in-place recycling in the example project of DOR

Operation costs 23.13 Baht/sq.m.

6.63, 29%

11.69, 50%

4.29, 19%

0.52, 2%

Administrative costs

Interest cost

Profit

VAT
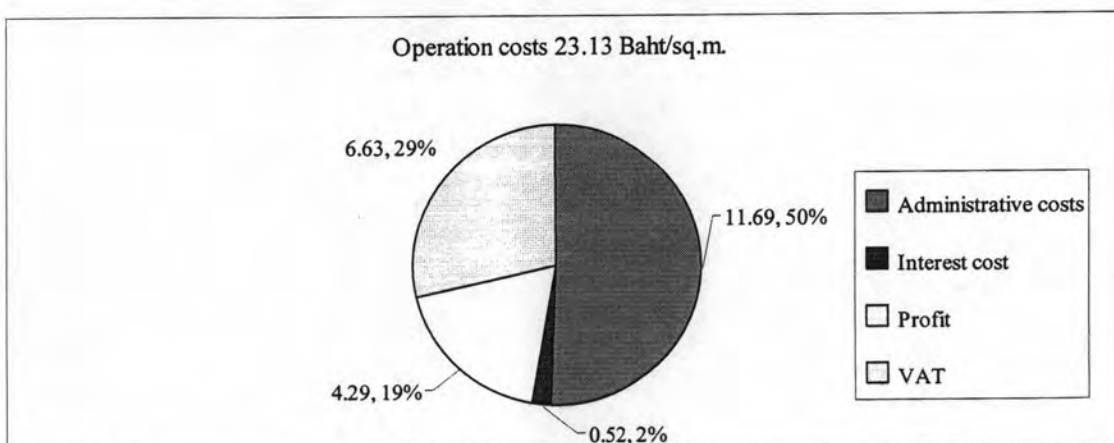
Figure 3.12 Proportion of costs in operation costs of pavement in-place recycling in the example project of DOR

From Figure 3.13, the largest proportion of costs in direct costs is cement costs 45% and then maintenance costs 23%, depreciation costs 17%, investment costs 5%, fuel costs 5%, traffic factor 1%, operator costs 1%, lubricant costs 1%, labor costs 1%, and tire costs less than 1% respectively.

All components of costs affecting operation costs of pavement in-place recycling can be added in Figure 3.12 to show the proportion of all costs in operation costs of pavement in-place recycling in the example project of DOR as shown in Figure 3.14. Operation costs that are 23.13 Baht/m^2 consist of 9 costs: contracting costs 0.54 Baht/m^2, site office costs 1.00 Baht/m^2, vehicles costs 4.07 Baht/m^2, staff costs 4.21 Baht/m^2, headquarter costs 1.40 Baht/m^2, risks costs 0.23 Baht/m^2, interest costs 0.52 Baht/m^2, profit 4.29 Baht/m^2, and VAT 6.63 Baht/m^2.
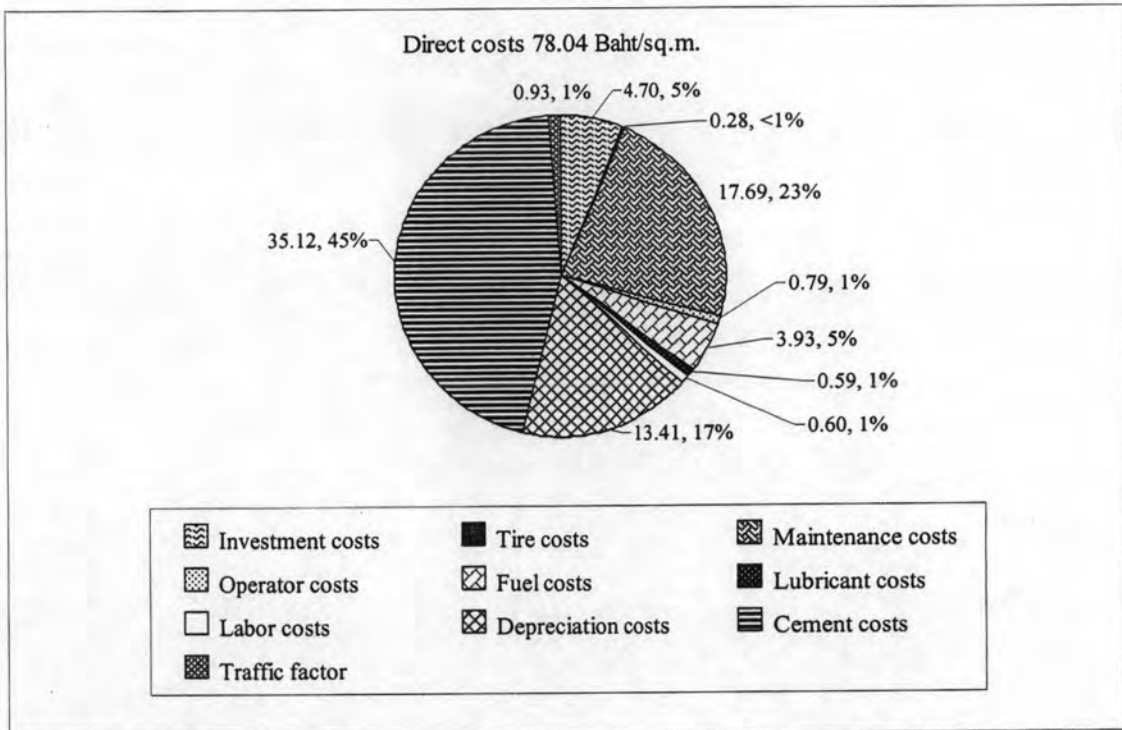
From Figure 3.14, The largest proportion of costs in operation costs is VAT 28% and then profit 19%, staff costs 18%, vehicles costs 18%, headquarter costs 5%, site office costs 4%, contracting costs 2%, interest costs 2%, and risks costs 1% respectively.

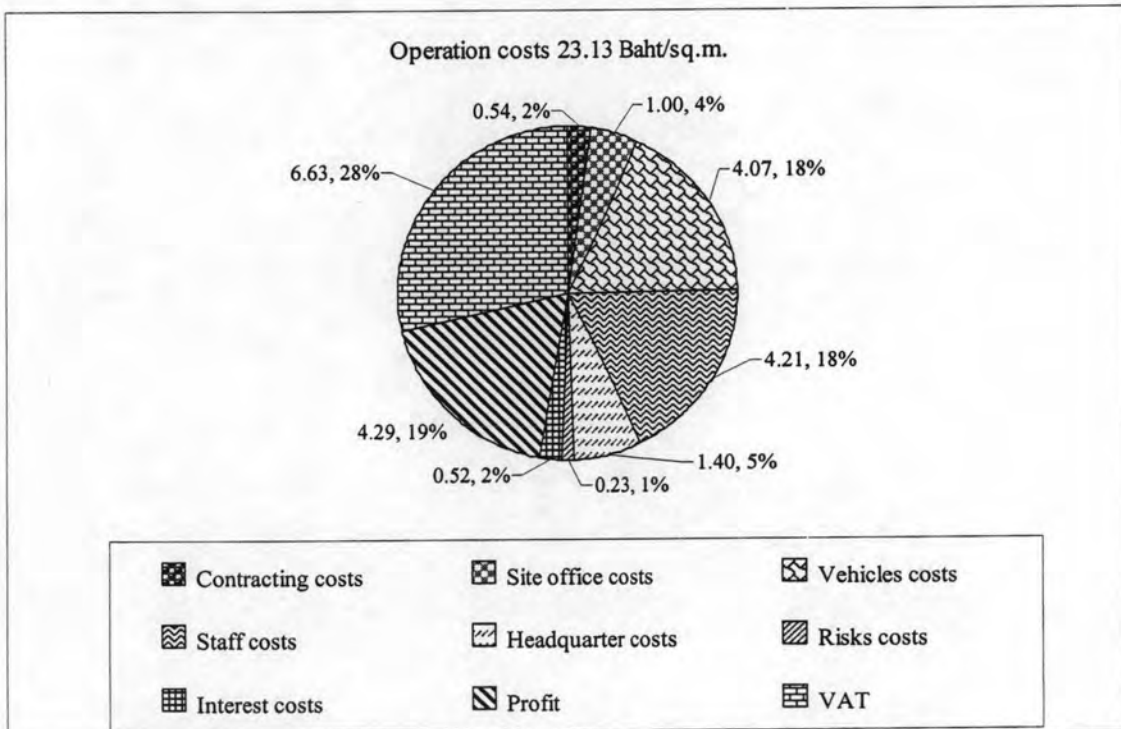All costs affecting direct costs in Figure 3.13 and all costs affecting operation costs in Figure 3.14 can be combined to show the proportion of all costs in total costs of pavement in-place recycling in the example project of DOR as shown in Figure 3.15. Total costs that are 101.17 Baht/m^2 will consist of 19 costs: investment costs 4.70 Baht/m^2, tire costs 0.28 Baht/m^2, maintenance costs 17.69 Baht/m^2, operator costs 0.79 Baht/m^2, fuel costs 3.93 Baht/m^2, lubricant costs 0.59 Baht/m^2, labor costs 0.60 Baht/m^2, depreciation costs 13.41 Baht/m^2, cement costs 35.12 Baht/m^2, and traffic factor 0.93 Baht/m^2, contracting costs 0.54 Baht/m^2, site office costs 1.00 Baht/m^2, vehicles costs 4.07 Baht/m^2, staff costs 4.21 Baht/m^2, headquarter costs 1.40 Baht/m^2, risks costs 0.23 Baht/m^2, interest costs 0.52 Baht/m^2, profit 4.29 Baht/m^2, and VAT 6.63 Baht/m^2.

Direct costs 78.04 Baht/sq.m.

0.93, 1% 4.70, 5%
0.28, <1%
17.69, 23%
35.12, 45%
0.79, 1%
3.93, 5%
0.59, 1%
0.60, 1%
13.41, 17%

⊞ Investment costs   ■ Tire costs   ▨ Maintenance costs
▨ Operator costs   ⊠ Fuel costs   ■ Lubricant costs
☐ Labor costs   ⊠ Depreciation costs ≣ Cement costs
▨ Traffic factor

Figure 3.13 Proportion of all costs in direct costs of pavement in-place recycling in the example project of DOR

Operation costs 23.13 Baht/sq.m.

0.54, 2%   1.00, 4%
6.63, 28%
4.07, 18%
4.21, 18%
4.29, 19%
1.40, 5%
0.52, 2%   0.23, 1%

▦ Contracting costs   ▨ Site office costs   ⊠ Vehicles costs
▨ Staff costs   ▨ Headquarter costs   ▨ Risks costs
▦ Interest costs   ◩ Profit   ⊞ VAT

Figure 3.14 Proportion of all costs in operation costs of pavement in-place recycling in the example project of DOR

Total costs of Pavement in-place recycling 101.17 Baht/sq.m.
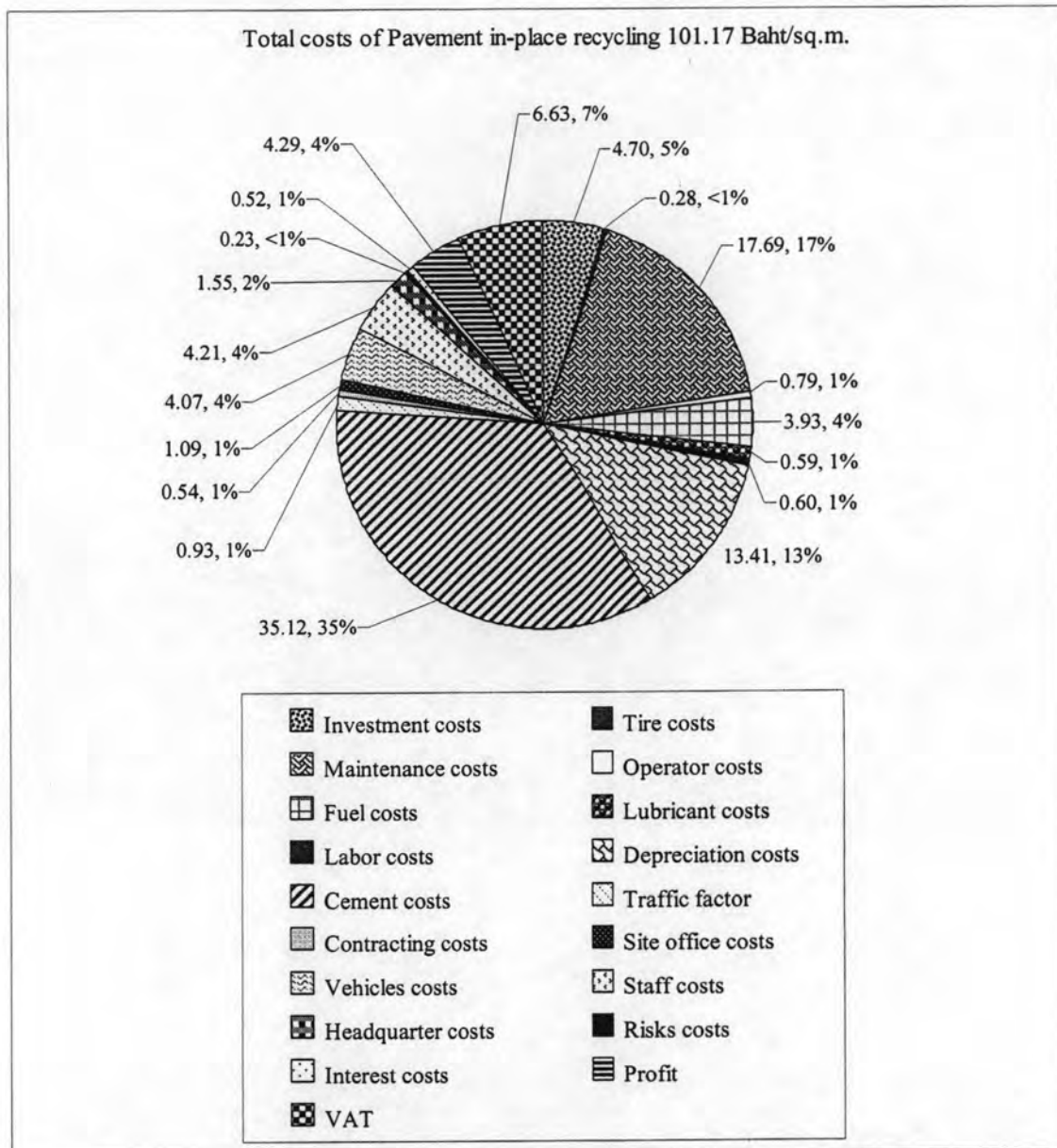
Figure 3.15 Total costs structure of pavement in-place recycling in the example project of DOR

From Figure 3.15, The largest proportion of costs in total costs is cement costs 35% and then maintenance costs 17%, depreciation costs 13%, VAT 7%, investment costs 5%, profit 4%, staff costs 3%, vehicles costs 3%, fuel costs 4%, headquarter costs 2%, site office costs 1%, traffic factor 1%, operator costs 1%, labor costs 1%, lubricant costs 1%, contracting costs 1%, interest costs 1%, tire costs less than 1%, and risks costs less than 1% respectively.

3.2 Total Costs Estimation in Pavement In-Place Recycling of the Contractor

Costs of the contractor in the construction project can be categorized into 2 types that are direct costs and indirect costs as following:

1. Direct costs are costs that directly relate to work. The direct costs consist of material costs, labor costs, and machine costs. Most direct costs in general construction are material and labor costs, but most direct costs in road construction are material and machine costs because the work in road construction deal with using machines.

2. Indirect Costs are general costs or overhead costs. The calculation of indirect costs may estimates from percent of material costs, labor costs, and machine costs or prices of work. The estimation by this method is possible to be mistake, so it has to separate costs in indirect costs as much as possible. The indirect costs may be comprised of drawings costs, bank guarantee costs, preparation costs, testing materials costs, temporary construction costs, machine transport costs, other equipment & machines costs, staff costs, facilities costs, vehicles costs, site office costs, headquarter costs, insurance costs, interest costs, risks costs, and VAT etc.

Machine costs in road construction can be categorized into 2 costs that are ownership costs and operating costs as equation 3.6.

$$C_{TOTAL} = C_{OWN} + C_{OP} \qquad (3.6)$$

by $\quad C_{TOTAL} = \quad$ Machine costs

$\quad C_{OWN} = \quad$ Ownership costs

$\quad C_{OP} = \quad$ Operating costs

1. Ownership costs (C_{OWN})

Ownership costs are costs from buying machine. These costs will be calculated either machine is operated or not. The ownership costs will consist of investment costs, depreciation costs, and tax, insurance, and storage costs.

1.1 Investment costs (C_I)

Investment costs are interest costs that have to pay from buying machine. The investment costs can be found from equation 3.7 as follows:

$$C_I \quad = \quad [(S + E) / 2] \times r \qquad (3.7)$$

by C_I =   Investment costs (Baht/year)

        S =   Start year price   (Baht)

        E =   End year price   (Baht)

        r =   % of investment interest

1.2 Depreciation costs (C_D)

Depreciation costs are value of machine that is continuously decreased due to its useful life. The depreciation will be highly decreased in first year and slowly decreased in next year. The value of machine after the end of useful life is called salvage value. Normally, useful life of machine is not less 5 years and salvage value is not less than 10%. The depreciation costs can be found by using the straight line method from equation 3.8 as follows:

$$C_D \quad = \quad (C - S) / n \qquad (3.8)$$

by C_D =   Depreciation costs (Baht/year)

        C =   New machine prices   (Baht)

        S =   Salvage value (Baht)

        n =   useful life (year)

1.3 Tax, insurance, and storage costs (C_S)

These costs consist of tax for machine ownership, insurance costs, and storage costs for keeping machine. The estimation for tax, insurance, and storage costs may uses 5 – 10% of new machine prices.

The ownership costs can be found from equation 3.9 as follows:

$$C_{OWN} = C_I + C_D + C_S \qquad (3.9)$$

by $\quad C_I \quad = \quad$ Investment costs

$\quad C_D \quad = \quad$ Depreciation costs

$\quad C_S \quad = \quad$ Tax, insurance, and storage costs

2. Operating Costs (C_{OP})

Operating costs will be happen when machine is used. The operating costs consist of fuel costs, lubricant costs, maintenance costs, tire costs, high-wear items costs, and operator costs.

2.1 Fuel Costs (C_F)

Fuel consumption depends on working condition and horse power (HP) of engine. Diesel engine use fuel 0.151 liter/hour/1HP that can find fuel consumption rate from equation 3.10. The fuel consumption rate also depends on operating condition (operating factor) that is easy, normal, or hard condition.

$$@_F = 0.151 \times \text{Operating Factor} \times \text{HP (Diesel engine)} \qquad (3.10)$$

By $\quad @_F \qquad = \quad$ Consumption rate (Liter/hour)

$\quad$ Operating Factor $\quad = \quad$ Operating condition (%)

$\quad$ HP $\qquad = \quad$ Horse power of engine

2.2 Lubricant, Filter, and Grease Costs (C_L)

Machines have to change lubricant for 3,000 km. or every 200 hours in normal operation condition. The lubricant consumption rate can be found from equation 3.11 as follows:

$$@_L = [(0.006 \times \text{Operating Factor} \times \text{HP}) / 7.4] + (C/T) \qquad (3.11)$$

by $@_L$ =   Consumption rate (Gallon/hour)

C   =   Capacity of engine (Gallon)

T   =   Numbers of hour to change lubricant   (hour)

2.3 Maintenance Costs (C_M)

Maintenance costs depend on type of machines and operation condition. When machine was new, maintenance costs was low and it will be increased due to its useful life. The maintenance costs can be found from equations 3.12 and 3.13 as follows:

$$C_M \quad = \quad (i \times C_{MT}) / \Sigma_I \qquad (3.12)$$

$$C_{MT} \quad = \quad a \times (C_i - S) \qquad (3.13)$$

by C_M =   Annual fixed costs (Baht/year)

C_{MT} =   All fixed costs (Baht)

C_i =   New machine prices (Baht)

S   =   Salvage value (Baht)

i   =   considering year

n   =   Useful life   (year)

a   =   Percent of repair (%)

Σ_I =   Summation of 1 to n

2.4 Tire Costs (C_T)

Tire costs consist of new tire costs and repairing costs. It's hard to estimate tire costs because it depends on working condition and many factors. Therefore, tire costs should use data from real working records.

2.5 High–Wear Items Costs (C_H)

Some type of machines has high-wear parts that have to change such as blade of tractor, cutter tool of cold recycler etc. These costs should use data from manufacturer.

2.6 Operator Costs (C_O)

Operator costs are costs that include salary, wages and other expense for machine drivers.

The operating costs can find from equation 3.14 as follows:

$$C_{OP} = C_F + C_L + C_M + C_T + C_H + C_O \qquad (3.14)$$

Machine costs can be found from ownership costs and operating costs in equations 3.9 and 3.11 as follows:

$$
\begin{aligned}
C_{TOTAL} &= C_{OWN} + C_{OP} \\
&= [C_I + C_D + C_S] + [C_F + C_L + C_M + C_T + C_H + C_O] \qquad (3.15)
\end{aligned}
$$

From direct costs and indirect costs estimation of road construction, we can use to draw flow chart for total costs estimation in pavement in-place recycling as shown in Figure 3.16. From the chart, we can categorize total costs of pavement in-place recycling into 2 parts that are comprised of direct costs and indirect costs as the following:

1. Direct Costs of Pavement In-Place Recycling

1.1 Cement costs

Material used in pavement in-place recycling is only Portland cement type I. The cement prices that the contractor uses for estimation comes from Bureau of Trade and Economics Indices Ministry of Commerce. The prices are defined as monthly prices in each province. Portland cement monthly prices (not included VAT) in 2007 can be shown in Table A.25 in Appendix A.

New machine prices		Fuel costs
Salvage value	→ Depreciation costs	Lubricant costs
Useful life		Maintenance costs

Machine prices		Tire costs
	→ Investment costs	High-wear items costs
Interest rate		Operator costs

| Tax, insurance, storage costs |

| Cement prices | Amount of cement | | Ownership costs | Operating costs |

| Cement costs | Labor costs | Machine costs |

Direct costs

Drawings costs		Vehicles costs
Bank guarantee costs		Site office costs
Preparation costs, Material test costs		Headquarter costs
Temporary construction costs		Insurance costs
Machine transport costs		Interest costs
Other equipments and machines costs		Risks costs
Staff costs		VAT
Facilities costs

Indirect costs

Total costs of pavement in-place recycling

Figure 3.16 Flow chart for total costs estimation in pavement in-place recycling of the contractor

1.2 Labor costs

Minimum daily wage in each province in 1 January 2007 can be shown in Table A.26 in Appendix A.

1.3 Machine costs

Pavement in-place recycling machine prices in this research are collected from S.D.C. International Co., Ltd. This company is a sale agency of pavement in-place recycling machine for brand CMI from USA. The prices of machines are CIF (Cost, Insurance, and Freight) price at Bangkok in April 2008. The prices can be shown in Table 3.16.

Table 3.16 New pavement in-place recycling machines prices

No.	List	Number	Price (Baht)
1.	PAVEMENT IN-PLACE RECYCLING MACHINE		34,000,000.00
1.1	COLD RECYCLER "CMI" Model: PRP-800-716, Year 2003 Engine CAT 3412 EDITTA, 860 HP Diesel Engine	1	
1.2	CEMENT SPREADER UNIT "CMI" Model: SRS-24	1	
2.	VIBRATING ROLLER		3,400,000.00
2.1	Vibrating Roller : DYNAPAC CA602D 190 HP 2001	1	

Source: S.D.C. International Co., Ltd.

Machines used in pavement in-place recycling consist of pavement in-place recycling machine and vibrating roller. The costs of these machines can find as following:

Pavement In-Place Recycling Machine Costs

1. Ownership cost (C_{OWN})

Ownership costs of pavement in-place recycling machine consist of investment costs, depreciation costs, and tax, insurance, and storage costs.

1.1 Investment costs (C_I)

Investment costs of pavement in-place recycling machine can be found from equation 3.7. Defining r = 7% and machine prices = 34,000,000 Baht, we can find investment costs as follows:

$$C_I \quad = \quad [(S + E) / 2] \times r$$

$$= \quad 34,000,000 \times 7/100$$

$$= \quad 2,380,000 \text{ Baht/year} \quad = \quad 1,190 \text{ Baht/hour}$$

1.2 Depreciation costs (C_D)

Depreciation costs of pavement in-place recycling machine can be found from equation 3.8. Defining C = 34,000,000 Baht, S = 3,400,000, n = 6 year and operating hours 2,000 Hours/year, we can find depreciation costs as follows:

$$C_D \quad = \quad (C - S) / n$$

$$= \quad (34,000,000 - 3,400,000) / 6$$

$$= \quad 5,100,000 \text{ Baht/year} \quad = \quad 2,550 \text{ Baht/hour}$$

1.3 Tax, insurance, and storage costs (C_S)

Defining tax 1%, insurance costs 3%, and storage costs 3%. Therefore, tax, insurance, and storage costs estimation is 7% of new machine prices.

$$C_S \quad = \quad 34,000,000 \times 7/100$$

$$= \quad 2,380,000 \text{ Baht/year} \quad = \quad 1,190 \text{ Baht/hour}$$

The ownership costs of pavement in-place recycling machine can be found from equation 3.9 as follows:

$$C_{OWN} \quad = \quad C_I + C_D + C_S$$

$$= \quad 2,380,000 + 5,100,000 + 2,380,000$$

$$= \quad 9,860,000 \text{ Baht/year}$$

$$\text{Or} \quad = \quad (2{,}380{,}000 + 5{,}100{,}000 + 2{,}380{,}000) / 2{,}000$$

$$= \quad 1{,}190 + 2{,}550 + 1{,}190$$

$$= \quad 4{,}930 \text{ Baht/hour}$$

2. Operating costs (C_{OP})

Operating costs of pavement in-place recycling machine in this research uses data from S.D.C. International Co., Ltd. The machines are comprised of Cold Recycler "CMI" model: PRP-800-716 and Cement Spreader Unit "CMI" model: SRS-24. Defining fuel prices 29.50 Baht/liter, recycling depth 20 cm, operating rate 300 m./hour, working hour 8 hours/day, average working rate 3,500 m^2/day, The operating costs can be shown in Table 3.17.

Table 3.17 Operating cost of pavement in-place recycling machines

List	Cold Recycler "CMI" Model: PRP-800-716	Cement Spreader Unit "CMI" Model: SRS-24	Total (Baht/hr.)
Fuel costs @ 97 Liter/hr.	@ 82 Liter/hr. 2,419.00	@ 15 Liter/hr. 442.50	2,861.50
Lubricant costs	120.00	80.00	200.00
Hydraulic oil costs	45.00	20.00	65.00
Filter costs	200.00	80.00	280.00
Maintenance costs	50.00	10.00	60.00
Tire costs	-	20.00	20.00
Cutting tool costs	1,150.00	-	1,150.00
Blade costs	-	20.00	20.00
Operator costs	100.00	100.00	200.00
Operating costs	4,084.00	772.50	4,856.50

Source: S.D.C. International Co., Ltd.

2.1 Fuel costs (C_F)

Fuel costs of pavement in-place recycling machine can be found from Table 3.17 that consist of cold recycler 2,419.00 Bath/hour and cement spreader unit 442.50 Bath/hour. The fuel costs of pavement in-place recycling machine is equal 2,419.00 + 442.50 = 2,861.50 Bath/hour.

2.2 Lubricant, filter, and grease costs (C_L)

Lubricant, filter, and grease costs of pavement in-place recycling machine can be found from Table 3.17 that consist of lubricant costs,

hydraulic oil costs, and filter costs. The costs of cold recycler are 120.00 + 45.00 + 200.00 = 365.00 Bath/hour. The costs of cement spreader unit are 80.00 +20.00 + 80.00 = 180.00 Bath/hour. The lubricant, filter, and grease costs are equal to 365.00 + 180.00 = 545.00 Bath/hour.

2.3 Maintenance costs (C_M)

Maintenance costs of pavement in-place recycling machine can find from Table 3.17 that consists of cold recycler 50.00 Bath/hour and cement spreader unit 10.00 Bath/hour. The maintenance costs is equal 50.00 + 10.00 = 60.00 Bath/hour.

2.4 Tire costs (C_T)

Tire costs can be found from Table 3.17. The tire costs have only in cement spreader unit 20.00 Bath/hour.

2.5 High–wear items costs (C_H)

High–wear items costs of pavement in-place recycling machine can be found from Table 3.17 that consists of cutting tools costs of cold recycler 1,150.00 Bath/hour and blade costs of cement spreader unit 20.00 Bath/hour. The high–wear items costs is equal 1,150.00 + 20.00 = 1,170.00 Bath/hour.

2.6 Operator costs (C_O)

Operator costs of pavement in-place recycling machine can be found from Table 3.17 consists of cold recycler 100.00 Bath/hour and cement spreader unit 100.00 Bath/hour. The operator costs is equal 100.00 + 100.00 = 200.00 Bath/hour.

The operating costs can find from equation 3.14 as follows:

$$C_{OP} = C_F + C_L + C_M + C_T + C_H + C_O$$

$$= 2,861.50 + 545.00 + 60.00 + 20.00 + 1,170.00 + 200.00$$

$$= 4,856.50 \quad \text{Bath/hour}$$

Machine costs of pavement in-place recycling machine can be found from equation 3.15 as follows:

$$C_{TOTAL} = C_{OWN} + C_{OP}$$

$$= 4,930 + 4,856.50 = 9,786.50 \text{ Bath/hour}$$

$$or = 78,292 \text{ Bath/day}$$

$$or = 22.37 \text{ Bath/m}^2$$

Vibrating Roller Costs

1. Ownership Costs (C_{OWN})

Ownership costs of vibrating roller consist of investment costs, depreciation costs, and tax, insurance, and storage costs.

1.1 Investment costs (C_I)

Investment costs of vibrating roller can be found from equation 3.7. Defining r = 7% and machine prices = 3,400,000 Baht, we can find investment costs as follows:

$$C_I = [(S + E) / 2] \times r$$

$$= 3,400,000 \times 7/100$$

$$= 238,000 \text{ Bath/year} = 119.00 \text{ Bath/hour}$$

1.2 Depreciation costs (C_D)

Depreciation costs of vibrating roller can be found from equation 3.8. Defining C = 3,400,000 Baht, S = 340,000 Baht, n = 6 year and operating hours 2,000 Hours/year, we can find depreciation costs as follows:

$$C_D = (C - S) / n$$

$$= (3,400,000 - 340,000) / 6$$

$$= 510,000 \text{ Bath/year} = 255.00 \text{ Bath/hour}$$

1.3 Tax, insurance, and storage costs (C_S)

Defining tax 1%, insurance costs 3%, and storage costs 3%. Therefore, tax, insurance, and storage costs estimation is 7% of new machine prices.

$$C_S \quad = \quad 3,400,000 \times 7/100$$

$$= \quad 238,000 \text{ Bath/year} \quad = \quad 119.00 \text{ Bath/hour}$$

The ownership costs of pavement in-place recycling machine can be found from equation 3.9 as follows:

$$C_{OWN} \quad = \quad C_I + C_D + C_S$$

$$= \quad 238,000 + 510,000 + 238,000$$

$$= \quad 986,000 \text{ Bath/year}$$

$$\text{or} \quad = \quad (238,000 + 510,000 + 238,000) / 2,000$$

$$= \quad 119.00 + 255.00 + 119.00$$

$$= \quad 493.00 \text{ Bath/hour}$$

2. Operating costs (C_{OP})

Operating costs of vibrating roller consist of fuel costs, lubricant costs, maintenance costs, tire costs, high-wear items costs, and operator costs. Each costs can be found as following:

2.1 Fuel costs (C_F)

Fuel consumption rate of vibrating roller can find from equation 3.10. Defining vibrating roller 190 HP and operating factor 80%, we can find fuel consumption rate as follows:

$$@_F \quad = \quad 0.151 \times \text{Operating Factor} \times \text{HP}$$

$$= \quad 0.151 \times 80/100 \times 190 \quad = \quad 22.952 \text{ Liter/hour}$$

Defining fuel prices 29.50 Baht/liter, so the fuel costs of vibrating roller is equal to $22.952 \times 29.50 = 677.10$ Baht/hour

2.2 Lubricant, filter, and grease costs (C_L)

Lubricant consumption rate of vibrating roller can be found from equation 3.11. Defining vibrating roller 190 HP, operating factor 80%, and $C = 8$ gallon, we can find the lubricant consumption rate as follows:

$$C_L = [(0.006 \times \text{Operating Factor} \times \text{HP}) / 7.4] + (C/T)$$

$$= [(0.006 \times 80/100 \times 190) / 7.4] + (8/200)$$

$$= 0.16 \quad \text{gallon/hour}$$

Defining lubricant prices 1,200 Baht/gallon, so the lubricant costs of vibrating roller is equal to $0.16 \times 1,200 = 192.00$ Baht/hour

2.3 Maintenance costs (C_M)

Maintenance costs of vibrating roller can find from equations 3.12 and 3.13. Defining $C_i = 3,400,000$ Baht, $S = 340,000$ Baht, $n = 6$ year, and percent of repair $a = 50\%$, we can find the maintenance costs as follows:

$$C_{MT} = a \times (C_i - S)$$

$$= 50/100 \times (3,400,000 - 340,000) = 1,530,000 \text{ Baht}$$

$$C_M = (i \times C_{MT}) / \sum I$$

$$= (1 \times 1,530,000) / 21$$

$$= 72,857 \text{ Baht/year} = 36.43 \text{ Baht/hour}$$

2.4 Tire costs (C_T)

There are no tire costs in vibrating roller.

2.5 High–wear items costs (C_H)

There are no high-wear items costs in vibrating roller.

2.6 Operator costs (C_O)

Operator costs of vibrating roller are 100.00 Bath/hour.

The operating costs can be found from equation 3.14 as follows:

$$C_{OP} = C_F + C_L + C_M + C_T + C_H + C_O$$

$$= 677.10 + 192.00 + 36.43 + 100.00$$

$$= 1005.53 \quad \text{Bath/hour}$$

Machine costs of pavement in-place recycling machine can be found from equation 3.15 as follows:

$$C_{TOTAL} = C_{OWN} + C_{OP}$$

$$= 493.00 + 1005.53 \quad = 1,498.53 \quad \text{Bath/hour}$$

$$\text{Or} \quad = 11,988.24 \quad \text{Bath/day}$$

$$\text{Or} \quad = 3.38 \quad \text{Bath/m}^2$$

2. Indirect Costs of Pavement In-Place Recycling

2.1 Drawings costs

Drawings prices for bidding in projects of DOH and DOR is about 10,000 Baht/project.

2.2 Bank guarantee costs

Cost of bank guarantee consists of bid bond fee, performance bond fee, advanced payment bond fee, guarantee bond fee, and stamp duty.

Bid bond guarantee is at 5% of project prices for 3 – 6 months. The bank fee is 1.5% of guarantee prices.

Performance bond is guarantee at 5% of project prices for period 3 – 6 months. The bank fee is 2% of guarantee prices.

Advanced payment bond guarantee is at 15% of project prices. The bank fee is 2% of guarantee prices.

Guarantee bond depends on contract agreement for period 2 years. The bank fee is 1.5% of guarantee prices.

Stamp duty for making contract is 0.1% of project prices.

2.3 Preparation costs and material test costs

Preparation costs of pavement in-place recycling are expense for traffic control & traffic sign for operation in the road. Material test is a part of contract that consists of modified compaction test, unconfined compressive strength test. The numbers of sampling is identified in highway construction standard 213/2543 that has to take 1 sample every 100 m. or every 500 m^2 for 1 lane. The test costs of DOH in 2003 define modified compaction test 300 Baht/sample, unconfined compressive strength test 450 Baht/sample, coring 100 Baht/sample, pavement in-place recycling testing design 3,500 Baht/times.

2.4 Temporary construction costs

Temporary site office can use 20 – 40 feet container unit that can serve 5 – 8 men. Asking from contractors found that costs for rent container are about 7,000 Baht/month. The camp for staff and keeping materials and machines can be built by plank of wood and zinc that costs may be estimated at 1,000 Baht/m^2.

2.5 Machine transport costs

Pavement in-place recycling machine and vibrating roller can be transported to construction site by trailer truck. Asking from contractors found that costs of transporting machine to the site is about 20,000 Baht and exit the site is about 20,000 Baht. So, the machine transport costs are about 40,000 Baht/project.

2.6 Other equipments and machines costs

Other equipments and machines costs in pavement in-place recycling consist of costs of some type of machines such as tire roller and truck which use in some parts of work. The costs of some equipment that deal with service, maintenance and repairing work such as electric generator, water pump etc. Asking from contractors found that other equipments and machines costs may be lump sum or estimated at 1% of project prices.

2.7 Staff costs

Staff costs are salary or wage of all people in organization. The staff used in pavement in-place recycling project may be classified into administrative staff and management staff. The administrative staff is group of people working in administrating and control pavement in-place recycling task. These staff is comprised of project manager, engineer, foreman, mechanic technician. The management staff is group of people working in management and service.

2.8 Facilities costs

Facilities costs consist of electricity costs, water costs, and telephone costs. The costs depends on numbers of usages units.

2.9 Vehicles costs

Vehicles used in site may have 1 car and 1 pickup. The vehicles costs can be estimated at 30,000 Baht/month.

2.10 Site office costs

Site office costs consist of equipment cost in site office such as tables, chairs, stationary, office furniture, air conditions, computer etc. and also costs in making reports. Asking from contractors found that site office costs may be estimated at 1% of project prices.

2.11 Headquarter costs

Headquarter costs consist of salary of headquarter staff, office rent, office costs, insurance, reception costs etc. Asking from contractors found that headquarter costs may be estimated at 1 – 3% of project prices.

2.12 Insurance costs

The insurance in pavement in-place recycling project may have machine insurance, worker insurance and third person insurance depending on contract agreement. Asking from contractors found that insurance cost may be in range 0.2 – 0.4% of value of insurance.

2.13 Interest costs

Pavement in-place recycling project need lots of money for construction. Although DOH & DOR give advanced payment to the contractor for work preparation, this money can use only for some parts of materials and preliminary work. The advanced payment is also deducted in every payment. In addition there is retention money that has to be deducted in every payment in projects of DOH. Therefore, the contractor may have to lend money from the bank to use in business. The interest costs can be found from equation 3.16 as follows:

$$I = i/12\ [r/100+(T+D-1)\times a/100-(a+r)/100\times(T+1)/2-(D-1)] \qquad (3.16)$$

By   I   =   Interest costs (% of project prices)

         T   =   Project time (month)

         D   =   Paid period (month)

         a   =   advance payment (%)

         i   =   interest rate (%)

         r   =   retention money (%)

2.1.4 Risks costs

The risks are possibility of damages that may be take place in every activities of construction. Asking from contractors found that risks costs may be estimated at 1 – 3% of project prices.

2.15 VAT has rate at 7% of project prices.

3.2.1 Total Costs Estimation in Pavement In-Place Recycling of the Contractor in the Example Project of DOH

Total costs estimation of pavement in-place recycling of the contractor consist of 2 parts that are direct costs estimation and indirect costs estimation as following:

1. Direct Costs Estimation

1.1 Cement costs

DOH defines cement usage in pavement in-place recycling as follows:

Amount of cement (By RAP weight) = 4.00 %

Recycling depth = 20 cm.

The amount of cement can be found from Table 3.1 that is 0.0184 ton/m^2 and cement prices at Stun province in December 2007 can be found from Table D.1 in Appendix D that is 2,766.35 Baht/ton

So, the cement costs are equal to $0.0184 \times 2,766.35 = 50.90$ Baht/m^2

1.2 Labor costs

Labor costs can be found from minimum daily wage in Stun provinces in 2007 in Table E.1 in Appendix E that is 150 Baht/day. The numbers of laborer that is defined is 10 Men/day. Productivity of pavement in-place recycling is 3,500 m^2/day

So, labor costs are equal to $150 \times 10 = 1,500$ Baht/day or 1,500/3,500 = 0.43 Baht/m^2

1.3 Machine costs

Machines used in pavement in-place recycling consist of pavement in-place recycling machine and vibrating roller. By defining fuel prices 29.50 Baht/liter, the costs of these machines can be found as following:

Pavement in-place recycling machine costs $\quad = \quad 22.37 \quad$ Baht/m^2

Vibrating Roller costs $\qquad\qquad\qquad = \quad 3.38 \quad$ Baht/m^2

So, machine costs is equal to $\quad 22.37 + 3.38 \quad = \quad 25.75 \quad$ Baht/m^2

Direct costs of pavement in-place recycling in the example project of DOH are equal to $50.90 + 0.43 + 25.75 = 77.08$ Baht/m^2

2. Indirect Costs Estimation

2.1 Drawings costs

Defining drawings costs for bidding are 10,000 Baht/project

2.2 Bank guarantee costs

The total costs of pavement in-place recycling in the example project of DOH are 3,139,696 Baht. We can calculate bank guarantee costs as follows:

Bid bond fee $\qquad\qquad\qquad = 5\% \times 3{,}139{,}696 \times 1.5\% \times 3/12 = 589$ Baht

Performance bond fee $\qquad\quad = 5\% \times 3{,}139{,}696 \times 2\% \times 1 = 3{,}140$ Baht

Advanced payment bond fee $= 15\% \times 3{,}139{,}696 \times 2\% \times 1 = 9{,}419$ Baht

Guarantee bond fee $\qquad\quad = 15\% \times 3{,}139{,}696 \times 1.5\% \times 2 = 14{,}129$ Baht

Stamp duty $\qquad\qquad\qquad = 0.1\% \times 3{,}139{,}696 = 3{,}140$ Baht

Bank guarantee costs of pavement in-place recycling in the example project of DOH are equal to $= 589 + 3{,}140 + 9{,}419 + 14{,}129 + 3{,}140 = 30{,}417$ Baht/m^2

2.3 Preparation costs and material test costs

Preparation costs for traffic control & traffic sign are lump sum at 20,000 Baht. The numbers of test sampling is identified in highway construction standard 213/2543 that has to take 1 sample every 100 m. or every 500 m^2 for 1 lane. The amount of pavement in-place recycling work in the example project of DOH is 26,384 m^2, so the number of test sampling is 26,384/500 = 52 pieces. The material tests costs consists of coring $100 \times 52 = 5,200$ Baht, modified compaction test $300 \times 52 = 15,600$ Baht, unconfined compressive strength test $450 \times 52 = 23,400$ Baht, and pavement in-place recycling mixing design 3 times $3,500 \times 3 = 10,500$ Baht. In addition there is traveling costs for DOH officer to the collect sampling that is estimated at 20,000 Baht. Therefore, the preparation costs and material test costs is all equal $20,000 + 5,200 + 15,600 + 23,400 + 10,500 + 20,000 = 94,700$ Baht.

2.4 Temporary construction costs

The temporary site office made by air-condition container is estimated at 7,000 Baht/month. Labor camp is defined as 30 m^2. Materials and machines stores are defined as 100 m^2. So, the camp and stores about 130 m^2 costs $130 \times 1,000 = 130,000$ Baht. This temporary building can be used at least 12 months and used for other road construction work. Pavement in-place recycling of this example project can be done in 1 month, so the temporary construction costs that deal with can be estimated only 1 month. The costs can be estimate at $7,000 + (130,000 /12) = 17,833$ Baht.

2.5 Machine transport costs

The machine transport costs of pavement in-place recycling machine and vibrating roller are about 40,000 Baht/project.

2.6 Other equipments and machines costs

Other equipments and machines costs is estimated at 1% of project prices, so the costs are equal to $1\% \times 3,139,696 = 31,397$ Baht

2.7 Staff costs

The staff used in pavement in-place recycling project may be classified into administrative, control, management, and service staff. Defining position, number and salary of staff, we can estimate the staff cost as shown in Table 3.18.

Table 3.18 Staff costs in the example project of DOH

Type	Position	Number	Project time (month)	Salary (Baht)	Staff costs (Baht)
Administration	Project manager	1	1	60,000	60,000
Control	Engineer	1	1	30,000	30,000
	Foreman	2	1	15,000	15,000
Management	Secretary	1	1	20,000	20,000
	Accountancy	1	1	18,000	18,000
	Clerk	3	1	15,000	15,000
Service	Technician	1	1	15,000	15,000
	Driver	1	1	8,000	8,000
	Security guard	1	1	8,000	8,000
				Total	234,000

Defining pavement in-place recycling work in this project is done in 1 month. So, the staff costs are equal to 234,000 Baht.

2.8 Facilities costs

Facilities costs will consist of electricity costs, water costs, and telephone costs. The costs depends on numbers of usages units.

The electricity costs can be estimated by defining appliances in site that consists of light 40 Watt 20 pieces, air-conditioner 2,000 Watt 1 unit, PC computer 300 Watt 3 units, and other electric equipments 300 Watt 3 units. These appliances are used 12 hour/day. The amount of electricity usage is equal to 54 Units/day. The cost rate of electricity is 5 Baht/unit, so the electricity costs for 1 month of pavement in-place recycling work are $54 \times 30 \times 5 = 8,100$ Baht.

The water costs can be estimated by defining the amount of water used in pavement recycling work and used by staff. Pavement in-place recycling process needs water to mix with cement and RAP material, so the amount of water used in the process can be estimated at 500 m^3. The amount of water used for 20 people can be estimated at 20 m^3/day or 600 m^3/month. The cost rate of water is 15 Baht/ m^3, so the

water costs for 1 month of pavement in-place recycling work are $(500 + 600) \times 15 = 16,500$ Baht.

...The telephone costs can be estimated by defining the amount of telephone used by staff for pavement recycling work. Defining there are 3 telephones and each used 10 minutes/day. The cost rate of telephone is 3 Baht/minute, so the telephone costs for 1 month of pavement in-place recycling work are $3 \times 10 \times 3 \times 30 = 2,700$ Baht.

Form the electricity costs, water costs, and telephone costs estimation, we can calculate the facilities costs of pavement recycling in the example project of DOH are equal to $8,100 + 16,500 + 2,700 = 27,300$ Baht.

2.9 Vehicles costs

Vehicles used in site may have 1 car and 1 pickup. The vehicles costs can be estimated at 30,000 Baht/month.

2.10 Site office costs

Site office costs is estimated at 1% of project prices, so the costs are equal $1\% \times 3,139,696 = 31,397$ Baht

2.11 Headquarter costs

Headquarter costs is estimated at 2% of project prices, so the costs are equal $2\% \times 3,139,696 = 62,794$ Baht

2.12 Insurance costs

Defining value of insurance is 30,000,000 and costs of insurance are 0.4% of value of insurance. This insurance has protection in one year. The costs of insurance is $0.4\% \times 30,000,000 = 120,000$ Baht. For pavement in-place recycling in this example project, we define the work will be finished in 1 month. Therefore, the insurance costs that deal with pavement in-place recycling are only 1 month. The insurance costs can be estimated at $120,000 / 12 = 10,000$ Baht.

2.13 Interest costs

Interest costs can find from equation 3.16. Defining $T = 12$ month, $D = 3$ month, $a = 15\%$, $i = 7\%$, and $r = 10\%$ for the example project of DOH. The interest costs can be estimated as follows:

$$I = i/12\ [r/100 + (T+D-1) \times a/100 - (a+r)/100 \times (T+1)/2 - (D-1)]$$

$$= 7/12\ [10/100 + (12+3-1) \times 15/100 - (15+10)/100 \times (12+1)/2 - (3-1)]$$

$$= 0.8313\%\ \text{of project prices}$$

So, the interest costs are equal to $0.8313\% \times 3{,}139{,}696 = 26{,}100$ Baht

2.1.4 Risks costs

Risks costs are estimated at 1% of project prices, so the costs are equal to $1\% \times 3{,}139{,}696 = 31{,}397$ Baht

2.15 VAT

VAT is rate at 7% of project prices. So, VAT in this example project of DOH is equal to $3{,}139{,}696 - (3{,}139{,}696 / 1.07) = 205{,}401$ Baht.

Indirect costs of pavement in-place recycling in the example project of DOH are equal to $10{,}000 + 30{,}417 + 94{,}700 + 17{,}833 + 40{,}000 + 31{,}397 + 234{,}000 + 27{,}300 + 30{,}000 + 31{,}397 + 62{,}794 + 10{,}000 + 26{,}100 + 205{,}401 + 31{,}397 = 882{,}736$ Baht/m^2. The quantity of pavement in-place recycling work is 26,384 m^2, so indirect costs in unit cost are equal to $882{,}736 / 26{,}384 = 33.46$ Baht./m^2.

From direct costs 77.08 Baht./m^2 and indirect costs 33.46 Baht./m^2. Total costs of pavement in-place recycling of the contractor in the example project of DOH are equal to $77.08 + 33.46 = 110.54$ Baht./m^2

3.2.2 Analysis of Factors Affecting Total Costs of Pavement In-Place Recycling of the Contractor in the Example Project of DOH

Total costs of pavement in-place recycling of the contractor in the example project of DOH that are 110.54 Baht/m^2 can be divided into 2 parts that are comprised of direct costs and indirect costs.

Direct costs of pavement in-place recycling that are 77.08 Baht/m^2 will consist of 3 costs: cement costs 50.90 Baht/m^2, labor costs 0.43 Baht/m^2, and machine costs 25.75 Baht/m^2. Each costs can find as follows:

1) Cement costs that are 50.90 Baht/m^2 depend on 2 factors: cement prices and amount of cement

2) Labor costs that are 0.43 Baht/m^2 depend on 2 factors: minimum daily wage and numbers of laborer.

3) Machine costs that are 25.75 Baht/m^2 will consist of 2 costs: pavement in-place recycling machine costs 22.37 Baht/m^2 and vibrating roller costs 3.38 Baht/m^2.

Indirect costs of pavement in-place recycling that are 33.46 Baht/m^2 consist of 15 costs. The quantity of pavement in-place recycling work is 26,384 m^2, so the costs affecting indirect costs can be considered in unit cost as following:

1) Drawings costs are 10,000 Baht or 10,000/26,384 = 0.38 Baht/m^2

2) Bank guarantee costs are 30,417 Baht or 30,417/26,384 = 1.15 Baht/m^2

3) Preparation costs and material test costs are 94,700 Baht or 94,700/26,384 = 3.58 Baht/m^2

4) Temporary construction costs are 17,833 Baht or 17,833/26,384 = 0.68 Baht/m^2

5) Machine transport costs are 40,000 Baht or 40,000/26,384 = 1.52 Baht/m^2

6) Other equipments and machines costs are 31,397 Baht or 31,397/26,384 = 1.19 Baht/m^2

7) Staff costs are 234,000 Baht or $234,000/26,384 = 8.87$ Baht/m^2

8) Facilities costs are 27,300 Baht or $27,300/26,384 = 1.03$ Baht/m^2

9) Vehicles costs are 30,000 Baht or $30,000/26,384 = 1.14$ Baht/m^2

10) Site office costs are 31,397 Baht or $31,397/26,384 = 1.19$ Baht/m^2

11) Headquarter costs are 62,794 Baht or $62,794/26,384 = 2.38$ Baht/m^2

12) Insurance costs are 10,000 Baht or $10,000/26,384 = 0.38$ Baht/m^2

13) Interest costs are 26,100 Baht or $26,1000/26,384 = 0.99$ Baht/m^2

14) Risks costs are 31,397 Baht or $31,397/26,384 = 1.19$ Baht/m^2

15) VAT is 205,401 Baht or $205,401/26,384 = 7.79$ Baht/m^2

Pavement in-place recycling machine costs that are 22.37 Baht/m^2 will consist of 2 costs: ownership costs 4,930 Baht/hour or 11.27 Baht/m^2 and operating costs 4,856.50 Baht/hour or 11.10 Baht/ m^2. The ownership costs that are 11.27 Baht/m^2 consists of investment costs 2.72 Baht/m^2, depreciation costs 5.83 Baht/m^2, and tax insurance and storage costs 2.72 Baht/m^2. The factors affecting investment costs are machine prices 34,000,000 Baht and interest rate 7%. The factors affecting depreciation costs are machine prices 34,000,000 Baht, salvage value 3,400,000 Baht, and useful life 6 years. The operating costs consists of fuel costs 6.54 Baht/m^2, lubricant costs 1.25 Baht/m^2, maintenance costs 0.14 Baht/m^2, tire costs 0.05 Baht/m^2, high-wear items costs 2.67 Baht/m^2, and operator costs 0.46 Baht/m^2. The factors affecting fuel costs are power of engine 860 HP and fuel prices 29.50 Baht/liter.

Vibrating roller costs that are 3.38 Baht/m^2 consists of 2 costs: ownership costs 493.00 Baht/hour or 1.13 Baht/m^2 and operating costs 985.77 Baht/hour or 2.25 Baht/ m^2. The ownership costs that is 1.13 Baht/m^2 consists of investment costs 0.27 Baht/m^2, depreciation costs 0.59 Baht/m^2, and tax insurance and storage costs 0.27 Baht/m^2. The factors affecting investment costs are machine prices 3,400,000 Baht and interest rate 7%. The factors affecting depreciation costs are machine prices 3,400,000 Baht, salvage value 340,000 Baht, and useful life 6 years. The operating costs consists of fuel costs 1.54 Baht/m^2, lubricant costs 0.44 Baht/m^2, maintenance costs 0.04 Baht/m^2, and operator costs 0.23 Baht/m^2. The factors affecting fuel costs are power of engine 190 HP and fuel prices 29.50 Baht/liter.

3.2.3 Total Costs Structure of Pavement In-Place Recycling of the Contractor in the Example Project of DOH

The result of analysis of factors affecting total costs of pavement in-place recycling of the contractor in the example project of DOH in 3.2.2 can show in proportion of costs in total costs structure as following:

The proportion of costs in total costs of pavement in-place recycling of the contractor in the example project of DOH can be shown in Figure 3.17. Total costs that are 110.54 Baht/m^2 consist of direct costs 77.08 Baht/m^2 and operation costs 33.46 Baht/m^2. The largest proportion of costs in total costs is direct costs 70% and then operation costs 30% respectively.

The proportion of costs in direct costs of pavement in-place recycling of the contractor in the example project of DOH can be shown in Figure 3.18. Direct costs that are 77.08 Baht/m^2 consist of 3 costs: cement costs 50.90 Baht/m^2, labor costs 0.43 Baht/m^2, and machine costs 25.75 Baht/m^2. The largest proportion of costs in direct costs is cement costs 66% and then machine costs 33% and labor costs 1% respectively.
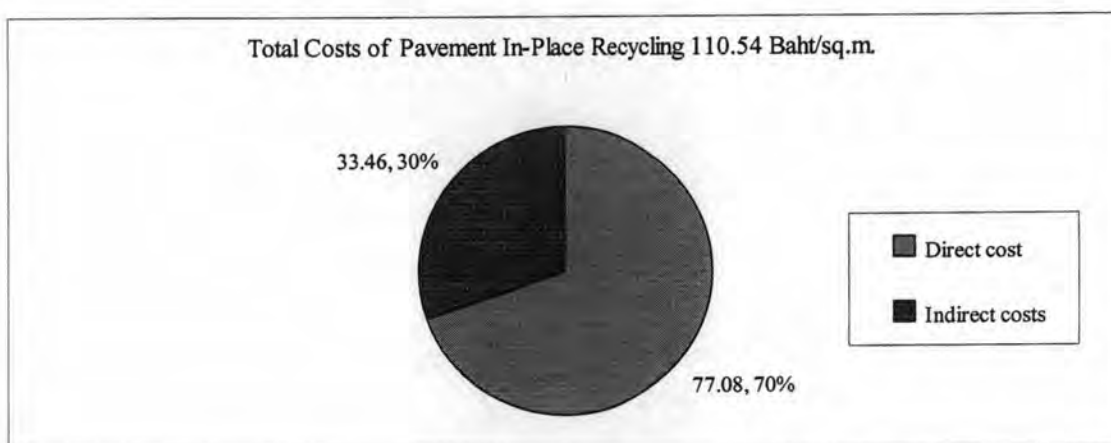

Figure 3.17 Proportion of costs in total costs of pavement in-place recycling of the contractor in the example project of DOH

All components of costs affecting direct costs can be combined in Figure 3.18 to show the proportion of all costs in direct costs of pavement in-place recycling of the contractor in the example project of DOH as shown in Figure 3.19. Direct costs that are 77.08 Baht/m^2 consist of 11 costs: cement costs 50.90 Baht/m^2, labor costs 0.43 Baht/m^2, depreciation costs 6.42 Baht/m^2, investment costs 2.99 Baht/m^2, tax insurance storage costs 2.99 Baht/m^2, fuel costs 8.08 Baht/m^2, lubricant costs 1.68 Baht/m^2, maintenance costs 0.18 Baht/m^2, high-wear items costs 2.67 Baht/m^2, tire costs 0.05 Baht/m^2, operator costs 0.69 Baht/m^2.

From Figure 3.19, The largest proportion of costs in direct costs is cement costs 67% and then fuel cost 10%, depreciation costs 8%, investment costs 4%, tax insurance storage costs 4%, high-wear items costs 3%, lubricant costs 2%, operator costs 1%, labor costs 1%, maintenance costs less than 1%, and tire costs 1 less than 1% respectively.

The proportion of costs in indirect costs of pavement in-place recycling of the contractor in the example project of DOH can be shown in Figure 3.20. Indirect costs that are 33.46 Baht/m^2 consist of 15 costs: drawings costs 0.38 Baht/m^2, bank guarantee costs 1.15 Baht/m^2, preparation costs and material test costs 3.58 Baht/m^2, temporary construction costs 0.68 Baht/m^2, machine transport costs 1.52 Baht/m^2, other equipments and machines costs 1.19 Baht/m^2, staff costs 8.87 Baht/m^2, facilities costs 1.03 Baht/m^2, vehicles costs 1.14 Baht/m^2, site office costs 1.19 Baht/m^2, headquarter costs 2.38 Baht/m^2, insurance costs 0.38 Baht/m^2, interest costs 0.99 Baht/m^2, VAT 7.79 Baht/m^2, risks costs 1.19 Baht/m^2.
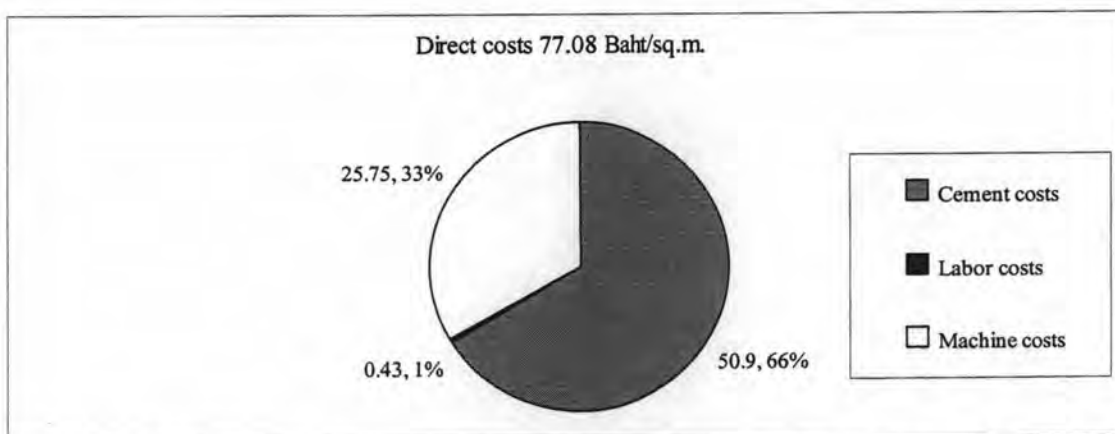

Figure 3.18 Proportion of costs in direct costs of pavement in-place recycling of the contractor in the example project of DOH
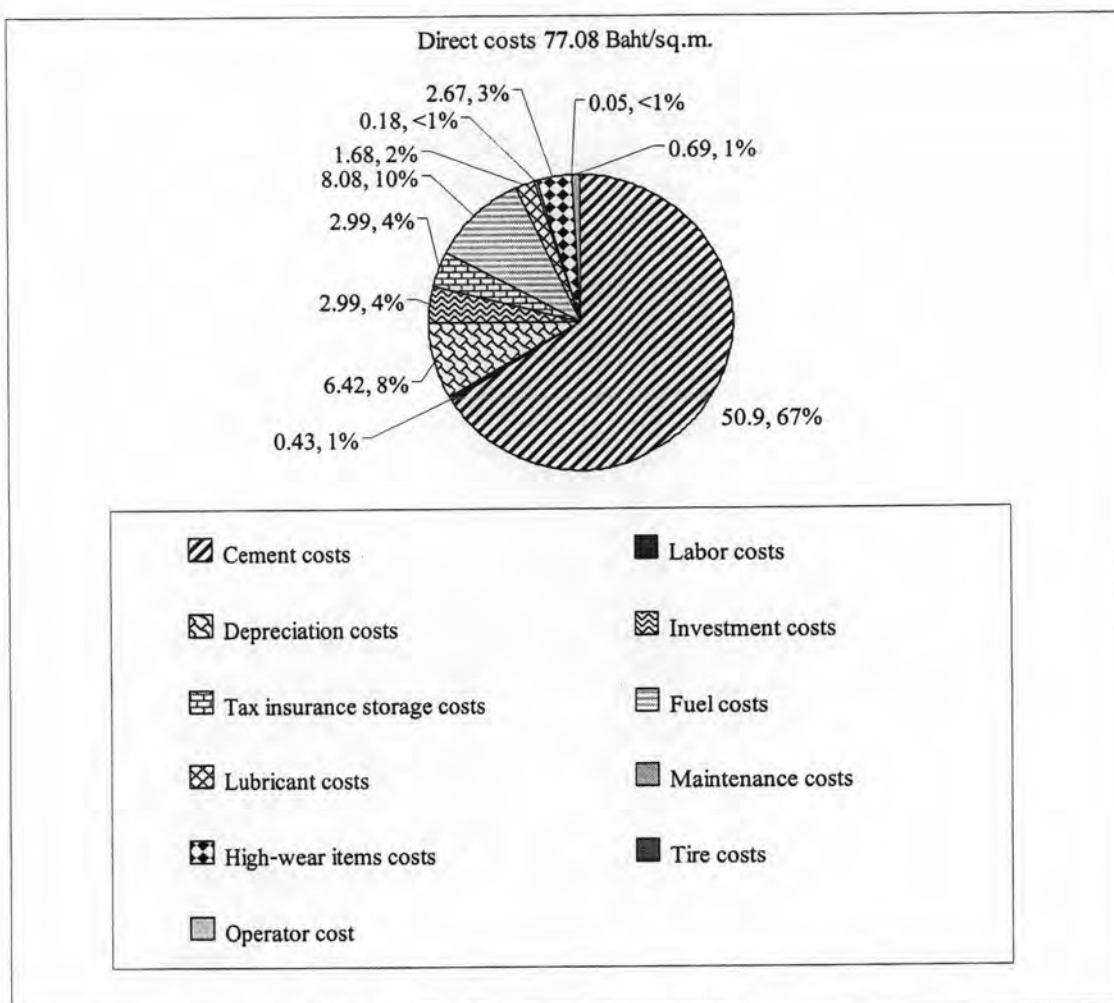
Direct costs 77.08 Baht/sq.m.

2.67, 3%
0.18, <1%
1.68, 2%
8.08, 10%
2.99, 4%
2.99, 4%
6.42, 8%
0.43, 1%
0.05, <1%
0.69, 1%
50.9, 67%

- ▨ Cement costs
- ■ Labor costs
- ▨ Depreciation costs
- ▨ Investment costs
- ▦ Tax insurance storage costs
- ▤ Fuel costs
- ▨ Lubricant costs
- ▨ Maintenance costs
- ▣ High-wear items costs
- ■ Tire costs
- ▨ Operator cost

Figure 3.19 Proportion of all costs in direct costs of pavement in-place recycling of the contractor in the example project of DOH

From Figure 3.20, The largest proportion of costs in indirect costs is staff costs 26% and then VAT 23%, preparation costs and material test costs 11%, headquarter costs 7%, machine transport costs 5%, risks costs 4%, site office costs 4%, other equipments and machines costs 4%, bank guarantee costs 3%, vehicles costs 3%, facilities costs 3%, interest costs 3%, temporary construction costs 2%, insurance costs 1%, and drawings costs 1% respectively.

All costs affecting direct cost in Figure 3.19 and all costs affecting operation costs in Figure 3.20 can be combined to show the proportion of all costs in total cost of pavement in-place recycling of the contractor in the example project of DOH as shown in Figure 3.21. Total costs that are 110.54 Baht/m^2 consist of 26 costs.

From Figure 3.20, The largest proportion of costs in total costs is cement costs 46% and then staff costs 8%, VAT 7%, fuel costs 7%, depreciation costs 6%, investment costs 3%, tax insurance storage costs 3%, preparation costs and material test costs 3%, headquarter costs 2%, high-wear items costs 2%, lubricant costs 2%, tax insurance storage costs 1%, operator costs 1%, bank guarantee costs 1%, , temporary construction costs 1%, machine transport costs 1%, other equipments and machines costs 1%, facilities costs 1%, vehicles costs 1%, site office costs 1%, interest costs 1%, risks costs 1%, maintenance costs less than 1%, tire costs less than 1%, labor costs less than 1%, insurance costs less than 1%, drawings costs less than 1% respectively.
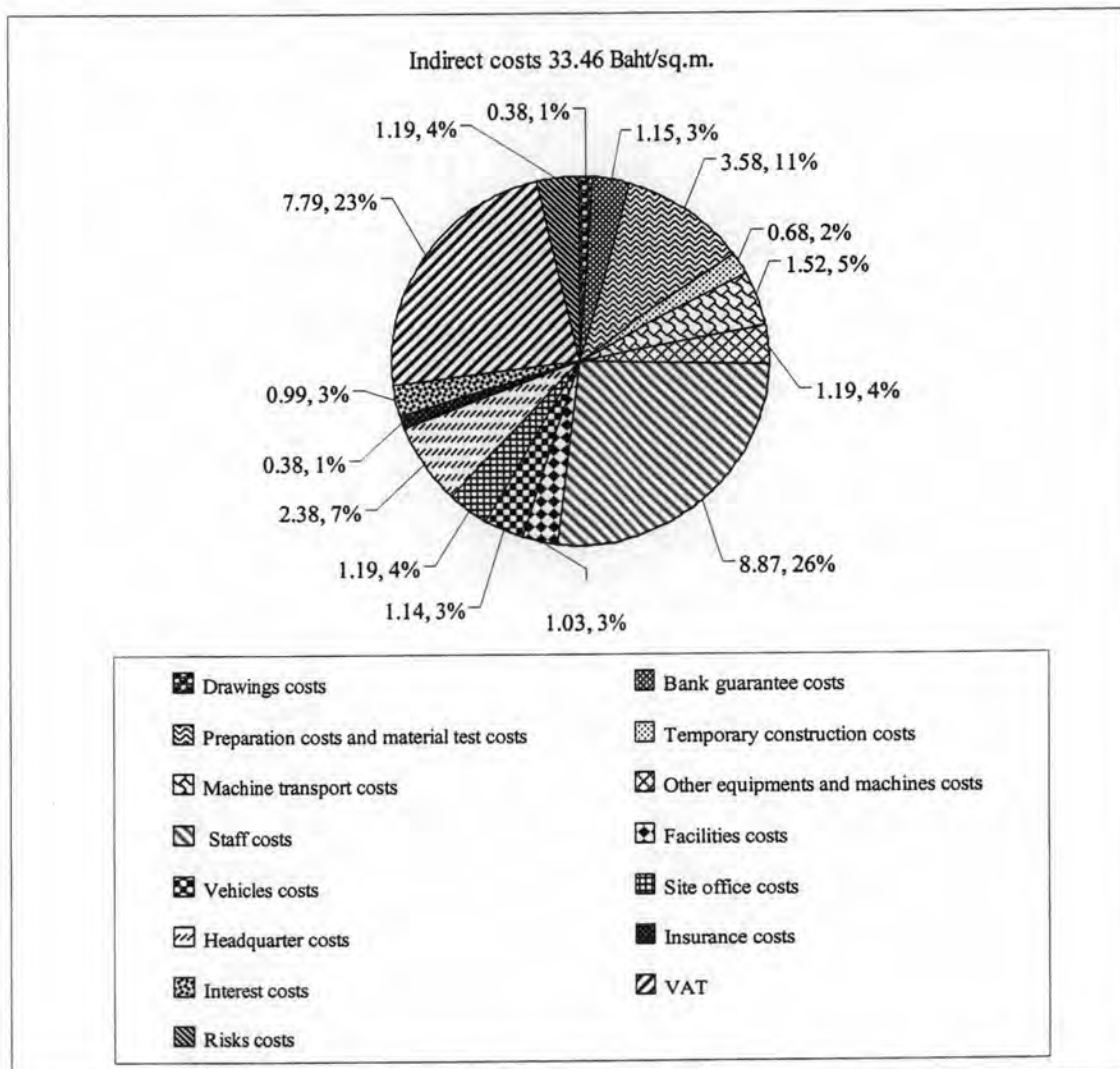

Figure 3.20 Proportion of all costs in indirect costs of pavement in-place recycling of the contractor in the example project of DOH
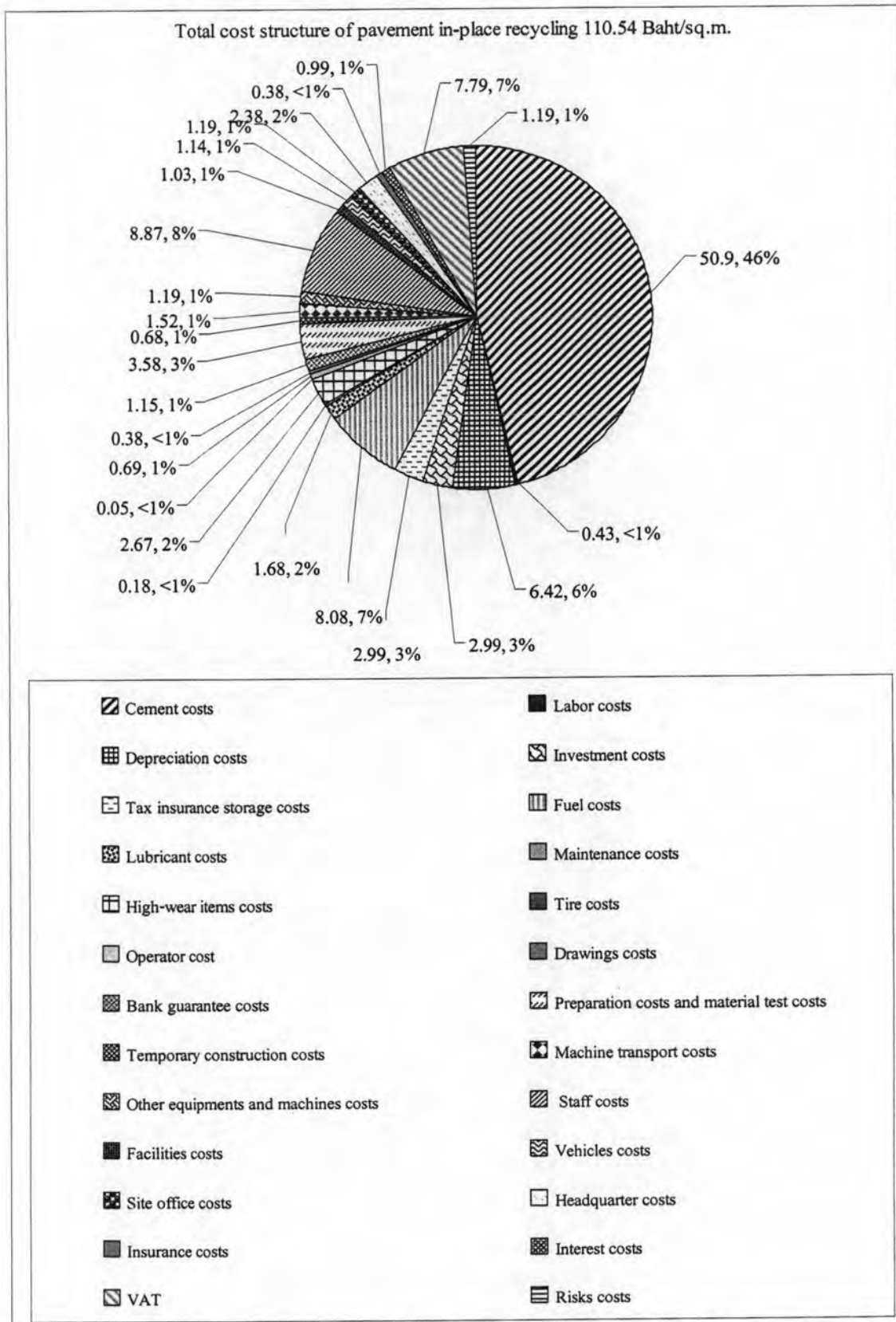
Total cost structure of pavement in-place recycling 110.54 Baht/sq.m.

0.99, 1%
0.38, <1%
2.38, 2%
1.19, 1%
1.14, 1%
1.03, 1%
8.87, 8%
1.19, 1%
1.52, 1%
0.68, 1%
3.58, 3%
1.15, 1%
0.38, <1%
0.69, 1%
0.05, <1%
2.67, 2%
0.18, <1%

7.79, 7%
1.19, 1%
50.9, 46%
0.43, <1%
6.42, 6%
2.99, 3%
2.99, 3%
8.08, 7%
1.68, 2%

▨ Cement costs	■ Labor costs
▦ Depreciation costs	◩ Investment costs
⊡ Tax insurance storage costs	▥ Fuel costs
▦ Lubricant costs	▪ Maintenance costs
⊞ High-wear items costs	◼ Tire costs
▢ Operator cost	◼ Drawings costs
▩ Bank guarantee costs	▨ Preparation costs and material test costs
▨ Temporary construction costs	◪ Machine transport costs
▧ Other equipments and machines costs	▨ Staff costs
◼ Facilities costs	▧ Vehicles costs
▨ Site office costs	▢ Headquarter costs
▪ Insurance costs	▩ Interest costs
◨ VAT	▤ Risks costs

Figure 3.21 Total costs structure of pavement in-place recycling of the contractor in the example project of DOH

3.2.4 Total Costs Estimation in Pavement In-Place Recycling of the Contractor in the Example Project of DOR

Total costs estimation of pavement in-place recycling of the contractor consist of 2 parts that are direct costs estimation and indirect costs estimation as following:

1. Direct Costs Estimation

1.1 Cement costs

DOR defines cement usage in pavement in-place recycling as follows:

Amount of cement (By RAP weight)   =   3.50 %

Recycling depth   =   20   cm.

The amount of cement can be found from Table 3.2 that is 0.015 ton/m^2 and cement prices at Chiang Rai province in August 2007 can be found from Table D.1 in Appendix D that is 2,373.83 Baht/ton

So, the cement costs is equal to $0.015 \times 2,373.83 = 35.61$ Baht/m^2

1.2 Labor costs

Labor costs can be found from minimum daily wage in Chiang Rai province in 2007 in Table E.1 in Appendix E that is 146 Baht/day. The numbers of laborer that is defined is 10 Men/day. Productivity of pavement in-place recycling is 3,500 m^2/day. So, labor costs is equal to $146 \times 10 = 1,460$ Baht/day or $1,460 / 3,500 = 0.42$ Baht/m^2

1.3 Machine costs

Machines used in pavement in-place recycling consist of pavement in-place recycling machine and vibrating roller. By defining fuel prices 25.50 Baht/liter, the costs of these machines can be found as following:

Pavement in-place recycling machine costs   =   21.48   Baht/m^2

Vibrating Roller costs   =   3.17   Baht/m^2

So, the machine costs is equal to $21.48 + 3.17 = 24.65$ Baht/m^2

Direct costs of pavement in-place recycling in the example project of DOR are all equal to $35.61 + 0.42 + 24.65 = 60.68$ Baht/m^2

2. Indirect Costs Estimation

2.1 Drawings costs

Defining drawings costs for bidding are 10,000 Baht/project

2.2 Bank guarantee costs

The total costs of pavement in-place recycling in the example project of DOR are 2,167,058.57 Baht. We can calculate bank guarantee costs as follows:

Bid bond fee $= 5\% \times 2,167,058.57 \times 1.5\% \times 3/12 = 406$ Baht

Performance bond fee $= 5\% \times 2,167,058.57 \times 2\% \times 1 = 2,167$ Baht

Advanced payment bond fee $= 15\% \times 2,167,058.57 \times 2\% \times 1 = 6,501$ Baht

Guarantee bond fee $= 15\% \times 2,167,058.57 \times 1.5\% \times 2 = 9,752$ Baht

Stamp duty $= 0.1\% \times 2,167,058.57 = 2,167$ Baht

Bank guarantee costs of pavement in-place recycling in the example project of DOR are equal to $= 406 + 2,167 + 6,501 + 9,752 + 2,167 = 20,993$ Baht/m^2

2.3 Preparation costs and material test costs

Preparation costs for traffic control & traffic sign are lump sum at 20,000 Baht. The numbers of test sampling is identified in highway construction standard 213/2543 that has to take 1 sample every 100 m. or every 500 m^2 for 1 lane. The amount of pavement in-place recycling work in the example project of DOR is 26,384 m^2, so the number of test sampling is $21,420/500 = 43$ pieces. The material tests costs consists of coring $100 \times 43 = 4,300$ Baht, modified compaction test $300 \times 43 = 12,900$ Baht, unconfined compressive strength test $450 \times 43 = 19,350$ Baht, and pavement in-place recycling mixing design 3 times $3,500 \times 3 = 10,500$ Baht. In

addition there is traveling costs for DOR officer to the collect sampling that is estimated at 20,000 Baht. Therefore, the preparation costs and material test costs is all equal to 20,000 + 4,300 + 12,900 + 19,350 + 10,500 + 20,000 = 87,050 Baht.

2.4 Temporary construction costs

The temporary site office made by air-condition container is estimated at 7,000 Baht/month. Labor camp is defined as 30 m². Materials and machines stores are defined as 100 m². So, the camp and stores about 130 m² costs 130 × 1,000 = 130,000 Baht. This temporary building can be used at least 12 months and used for other road construction work. Pavement in-place recycling of this example project can be done in 1 month, so the temporary construction costs that deal with can be estimated only 1 month. The costs can be estimate at 7,000 + (130,000 /12) = 17,833 Baht.

2.5 Machine transport costs

The machine transport costs of pavement in-place recycling machine and vibrating roller are about 40,000 Baht/project.

2.6 Other equipments and machines costs

Other equipments and machines costs is estimated at 1% of project prices, so the costs are equal to 1% × 2,167,058.57 = 21,670 Baht

2.7 Staff costs

The staff used in pavement in-place recycling project may be classified into administrative, control, management, and service staff. Defining position, number and salary of staff, we can estimate the staff cost as shown in Table 3.18. Defining pavement in-place recycling work in this project is done in 1 month. So, the staff costs are equal to 234,000 Baht.

2.8 Facilities costs

Facilities costs consist of electricity costs, water costs, and telephone costs. The costs depends on numbers of usages units.

The electricity costs can be estimated by defining appliances in site that consists of light 40 Watt 20 pieces, air-conditioner 2,000 Watt 1 unit, PC computer 300 Watt 3 units, and other electric equipments 300 Watt 3 units. These appliances are used 12 hour/day. The amount of electricity usage is equal to 54 Units/day. The cost rate of electricity is 5 Baht/unit, so the electricity costs for 1 month of pavement in-place recycling work are $54 \times 30 \times 5 = 8,100$ Baht.

The water costs can be estimated by defining the amount of water used in pavement recycling work and used by staff. Pavement in-place recycling process needs water to mix with cement and RAP material, so the amount of water used in the process can be estimated at 350 m^3. The amount of water used for 20 people can be estimated at 20 m^3/day or 600 m^3/month. The cost rate of water is 15 Baht/ m^3, so the water costs for 1 month of pavement in-place recycling work are $(350 + 600) \times 15 = 14,250$ Baht.

The telephone costs can be estimated by defining the amount of telephone used by staff for pavement recycling work. Defining there are 3 telephones and each used 10 minutes/day. The cost rate of telephone is 3 Baht/minute, so the telephone costs for 1 month of pavement in-place recycling work are $3 \times 10 \times 3 \times 30 = 2,700$ Baht.

Form the electricity costs, water costs, and telephone costs estimation, we can calculate the facilities costs of pavement recycling in the example project of DOH are equal to $8,100 + 14,250 + 2,700 = 25,050$ Baht.

2.9 Vehicles costs

Vehicles used in site may have 1 car and 1 pickup. The vehicles costs can be estimated at 30,000 Baht/month.

2.10 Site office costs

Site office costs are estimated at 1% of project prices, so the costs are equal to 1% × 2,167,058.57 = 21,670 Baht

2.11 Headquarter costs

Headquarter costs are estimated at 2% of project prices, so the costs are equal to 2% × 2,167,058.57 = 43,340 Baht

2.12 Insurance costs

Defining value of insurance is 30,000,000 and costs of insurance are 0.4% of value of insurance. This insurance has protection in one year. The costs of insurance is 0.4% × 30,000,000 = 120,000 Baht. For pavement in-place recycling in this example project, we define the work will be finished in 1 month. Therefore, the insurance costs that deal with pavement in-place recycling are only 1 month. The insurance costs can be estimated at 120,000 / 12 = 10,000 Baht.

2.13 Interest costs

Interest costs can find from equation 3.16. Defining T = 9 month, D = 3 month, a = 15%, i = 7%, and r = 0% for the example project of DOH. The interest costs can be estimated as follows:

$$I = i/12 \left[r/100 + (T+D-1) \times a/100 - (a+r)/100 \times (T+1)/2 - (D-1) \right]$$

$$= 7/12 \left[0/100 + (9+3-1) \times 15/100 - (15+0)/100 \times (9+1)/2 - (3-1) \right]$$

$$= 0.6417\% \text{ of project prices}$$

So, the interest costs are equal to 0.6417% × 2,167,058.57 = 13,906 Baht

2.1.4 Risks costs

Risks costs are estimated at 1% of project prices, so the costs are equal to 1% × 2,167,058.57 = 21,670 Baht

2.15 VAT

VAT is rate at 7% of project prices. So, VAT in this example project of DOH is equal to $2,167,058.57 - (2,167,058.57 / 1.07) = 141,770$ Baht.

Indirect costs of pavement in-place recycling in the example project of DOH are equal to $10,000 + 20,993 + 87,050 + 21,444 + 40,000 + 21,670 + 234,000 + 25,050 + 30,000 + 21,670 + 43,340 + 10,000 + 13,906 + 141,770 + 21,670 = 742,563$ Baht/m^2. The quantity of pavement in-place recycling work is 21,420 m^2, so indirect costs in unit cost are equal to $742,563 / 21,420 = 34.67$ Baht./m^2.

From direct costs 60.68 Baht./m^2 and indirect costs 34.67 Baht./m^2. Total costs of pavement in-place recycling of the contractor in the example project of DOH are equal $60.68 + 34.67 = 95.35$ Baht./m^2

3.2.5 Analysis of Factors Affecting Total Costs of Pavement In-Place Recycling of the Contractor in the Example Project of DOR

Total costs of pavement in-place recycling of the contractor in example project of DOR that are 95.35 Baht/m^2 can be divided into 2 parts that are comprised of direct costs and indirect costs.

Direct costs of pavement in-place recycling that are 60.68 Baht/m^2 consist of 3 costs: cement costs 35.61 Baht/m^2, labor costs 0.42 Baht/m^2, and machine costs 24.65 Baht/m^2. Each costs can find as follows:

1) Cement costs that are 35.61 Baht/m^2 depend on 2 factors: cement prices and amount of cement

2) Labor costs that are 0.42 Baht/m^2 depend on 2 factors: minimum daily wage and numbers of laborer.

3) Machine costs that are 24.65 Baht/m^2 consist of 2 costs: pavement in-place recycling machine costs 21.48 Baht/m^2 vibrating roller costs 3.17 Baht/m^2.

Indirect costs of pavement in-place recycling that are 34.67 Baht/m^2 consist of 15 costs. The quantity of pavement in-place recycling work is 21,420 m^2, so the costs affecting indirect costs can be considered in unit costs as following:

1) Drawings costs are 10,000 Baht or 10,000/21,420 = 0.47 Baht/m2

2) Bank guarantee costs are 20,993 Baht or 20,993/21,420 = 0.98 Baht/m2

3) Preparation costs and material test costs are 87,050 Baht or 87,050/21,420 = 4.06 Baht/m2

4) Temporary construction costs are 17,833 Baht or 17,833/21,420 = 0.68 Baht/m2

5) Machine transport costs are 40,000 Baht or 40,000/21,420 = 1.87 Baht/m2

6) Other equipments and machines costs are 21,670 Baht or 21,670/21,420 = 1.01 Baht/m2

7) Staff costs are 234,000 Baht or 234,000/21,420 = 10.92 Baht/m2

8) Facilities costs are 25,050 Baht or 25,050/21,420 = 1.17 Baht/m2

9) Vehicles costs are 30,000 Baht or 30,000/21,420 = 1.40 Baht/m2

10) Site office costs are 21,670 Baht or 21,670/21,420 = 1.01 Baht/m2

11) Headquarter costs are 43,340 Baht or 43,340/21,420 = 2.02 Baht/m2

12) Insurance costs are 10,000 Baht or 10,000/21,420 = 0.47 Baht/m2

13) Interest costs are 13,906 Baht or 13,906/21,420 = 0.65 Baht/m2

14) Risks costs are 21,670 Baht or 21,670/21,420 = 1.01 Baht/m2

15) VAT is 141,770 Baht or 141,770 /21,420 = 6.62 Baht/m2

Pavement in-place recycling machine costs that are 21.48 Baht/m^2 consist of 2 costs: ownership costs 4,930 Baht/hour or 11.27 Baht/m^2 and operating costs 4,468.50 Baht/hour or 10.21 Baht/ m^2. The ownership costs that are 11.27 Baht/m^2 consist of investment costs 2.72 Baht/m^2, depreciation costs 5.83 Baht/m^2, and tax insurance and storage costs 2.72 Baht/m^2. The factors affecting investment costs are machine prices 34,000,000 Baht and interest rate 7%. The factors affecting depreciation costs are machine prices 34,000,000 Baht, salvage value 3,400,000 Baht, and useful life 6 years. The operating costs that are 10.21 Baht/ m^2 consists of fuel costs 5.64 Baht/m^2, lubricant costs 1.25 Baht/m^2, maintenance costs 0.14 Baht/m^2, tire costs 0.05 Baht/m^2, high-wear items costs 2.67 Baht/m^2, and operator costs 0.46 Baht/m^2. The factors affecting fuel costs are power of engine 860 HP and fuel prices 25.50 Baht/liter.

Vibrating roller costs that are 3.17 Baht/m^2 consist of 2 costs: ownership costs 493.00 Baht/hour or 1.13 Baht/m^2 and operating costs 893.94 Baht/hour or 2.04 Baht/ m^2. The ownership costs that are 1.13 Baht/m^2 consists of investment costs 0.27 Baht/m^2, depreciation costs 0.59 Baht/m^2, and tax insurance and storage costs 0.27 Baht/m^2. The factors affecting investment costs are machine prices 3,400,000 Baht and interest rate 7%. The factors affecting depreciation costs are machine prices 3,400,000 Baht, salvage value 340,000 Baht, and useful life 6 years. The operating costs that are 2.04 Baht/ m^2 consists of fuel costs 1.34 Baht/m^2, lubricant costs 0.44 Baht/m^2, maintenance costs 0.04 Baht/m^2, and operator costs 0.23 Baht/m^2. The factors affecting fuel costs are power of engine 190 HP and fuel prices 25.50 Baht/liter.

3.2.6 Total Costs Structure of Pavement In-Place Recycling of the Contractor in the Example Project of DOR

The result of analysis of factors affecting total costs of pavement in-place recycling of the contractor in the example project of DOR in 3.2.5 can show in proportion of costs in total costs structure as following:

The proportion of costs in total costs of pavement in-place recycling of the contractor in the example project of DOR can be shown in Figure 3.22. Total costs that are 95.35 Baht/m^2 consist of direct costs 60.68 Baht/m^2 and operation costs 34.67 Baht/m^2. The largest proportion of costs in total costs is direct costs 64% and then operation costs 36% respectively.

The proportion of costs in direct costs of pavement in-place recycling of the contractor in the example project of DOR can be shown in Figure 3.23. Direct costs that are 60.68 Baht/m^2 consist of 3 costs: cement costs 35.61 Baht/m^2, labor costs 0.42 Baht/m^2, and machine costs 24.65 Baht/m^2. The largest proportion of costs in direct costs is cement costs 58% and then machine costs 41% and labor costs 1% respectively.

Total Costs of Pavement In-Place Recycling 95.35 Baht/sq.m.

34.67, 36%

Direct cost

Indirect costs

60.68, 64%

Figure 3.22 Proportion of costs in total costs of pavement in-place recycling of the contractor in the example project of DOR

All components of costs affecting direct costs can be combined in Figure 3.23 to show the proportion of all costs in direct costs of pavement in-place recycling of the contractor in the example project of DOR as shown in Figure 3.24. Direct costs that are 60.68 Baht/m^2 consist of 11 costs: cement costs 35.61 Baht/m^2, labor costs 0.42 Baht/m^2, depreciation costs 6.42 Baht/m^2, investment costs 2.99 Baht/m^2, tax insurance storage costs 2.99 Baht/m^2, fuel costs 6.98 Baht/m^2, lubricant costs 1.69 Baht/m^2, maintenance costs 0.18 Baht/m^2, high-wear items costs 2.67 Baht/m^2, tire costs 0.05 Baht/m^2, operator costs 0.69 Baht/m^2.

From Figure 3.24, The largest proportion of costs in direct costs is cement costs 58% and then fuel cost 12%, depreciation costs 11%, investment costs 5%, tax insurance storage costs 5%, high-wear items costs 4%, lubricant costs 3%, operator costs 1%, labor costs 1%, maintenance costs less than 1%, and tire costs 1 less than 1% respectively.

The proportion of costs in indirect costs of pavement in-place recycling of the contractor in the example project of DOR can be shown in Figure 3.25. Indirect costs that are 34.67 Baht/m^2 consist of 15 costs: drawings costs 0.47 Baht/m^2, bank guarantee costs 0.98 Baht/m^2, preparation costs and material test costs 4.06 Baht/m^2, temporary construction costs 1.00 Baht/m^2, machine transport costs 1.87 Baht/m^2, other equipments and machines costs 1.01 Baht/m^2, staff costs 10.92 Baht/m^2, facilities costs 1.17 Baht/m^2, vehicles costs 1.40 Baht/m^2, site office costs 1.01 Baht/m^2, headquarter costs 2.02 Baht/m^2, insurance costs 0.47 Baht/m^2, interest costs 0.65 Baht/m^2, VAT 6.62 Baht/m^2, risks costs 1.01 Baht/m^2.
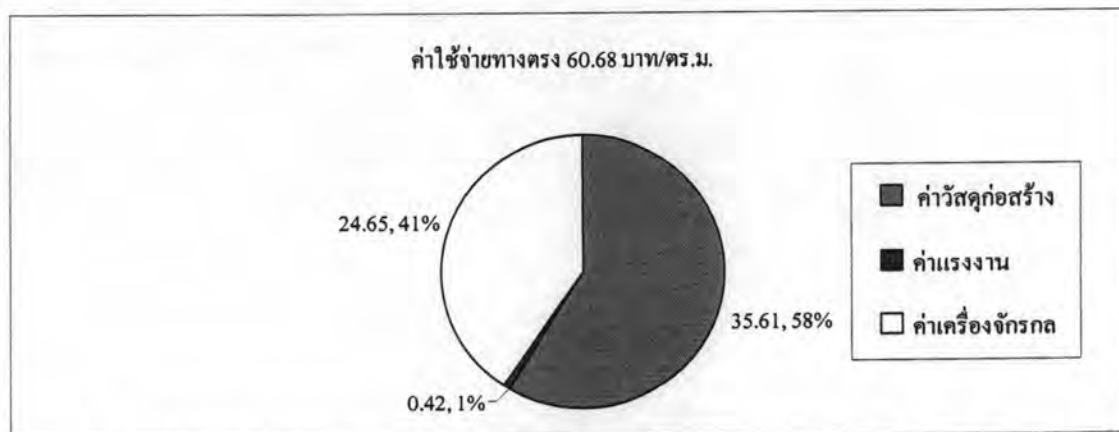

Figure 3.23 Proportion of costs in direct costs of pavement in-place recycling of the contractor in the example project of DOR
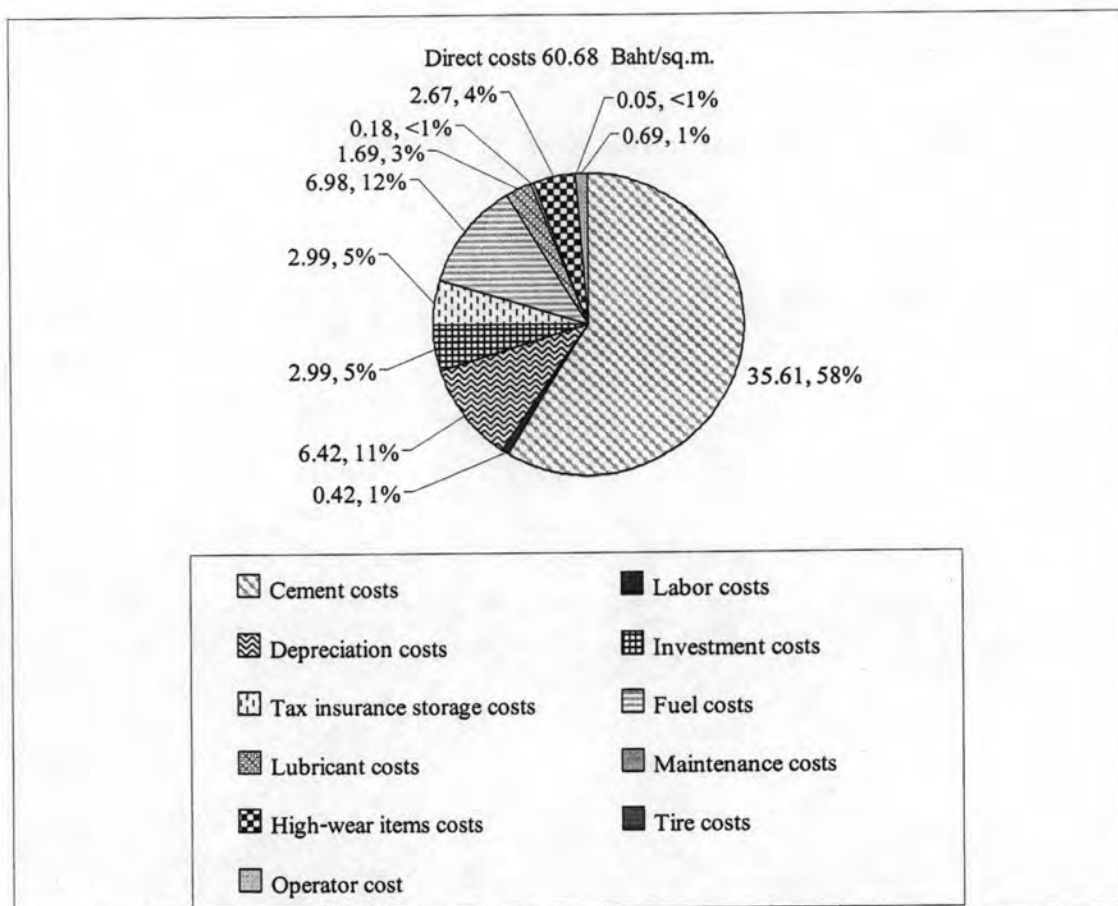
Figure 3.24 Proportion of all costs in direct costs of pavement in-place recycling of the contractor in the example project of DOR

From Figure 3.25, The largest proportion of costs in indirect costs is staff costs 32% and then VAT 19%, preparation costs and material test costs 12%, headquarter costs 6%, machine transport costs 5%, vehicles costs 4%, risks costs 3%, facilities costs 3%, site office costs 4%, other equipments and machines costs 3%, temporary construction costs 3%, bank guarantee costs 3%, interest costs 2%, insurance costs 1%, and drawings costs 1% respectively.

All costs affecting direct cost in Figure 3.24 and all costs affecting operation costs in Figure 3.25 can be combined to show the proportion of all costs in total costs of pavement in-place recycling of the contractor in the example project of DOH as shown in Figure 3.26. Total cost that is 95.35 Baht/m^2 will consist of 26 costs.

From Figure 3.26, The largest proportion of costs in total costs is cement costs 37% and then staff costs 11%, VAT 7%, fuel costs 7%, depreciation costs 7%, preparation costs and material test costs 4%, investment costs 3%, tax insurance storage costs 3%, high-wear items costs 3%, headquarter costs 2%, machine transport costs 2%, lubricant costs 2%, tax insurance storage costs 1%, operator costs 1%, bank guarantee costs 1%, , temporary construction costs 1%, other equipments and machines costs 1%, facilities costs 1%, vehicles costs 1%, site office costs 1%, interest costs 1%, risks costs 1%, maintenance costs less than 1%, tire costs less than 1%, labor costs less than 1%, insurance costs less than 1%, drawings costs less than 1% respectively.
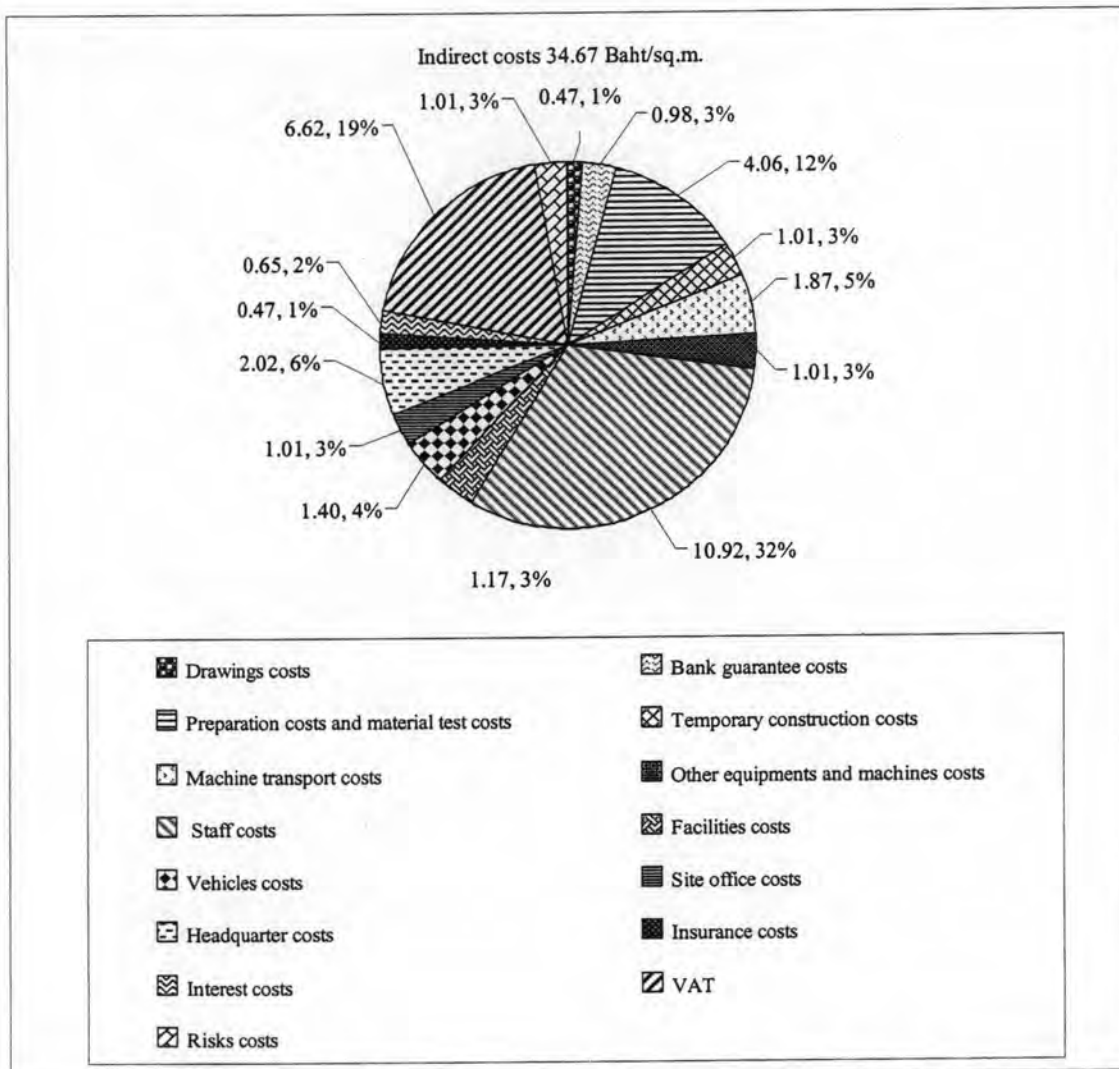

Figure 3.25 Proportion of all costs in indirect costs of pavement in-place recycling of the contractor in the example project of DOR
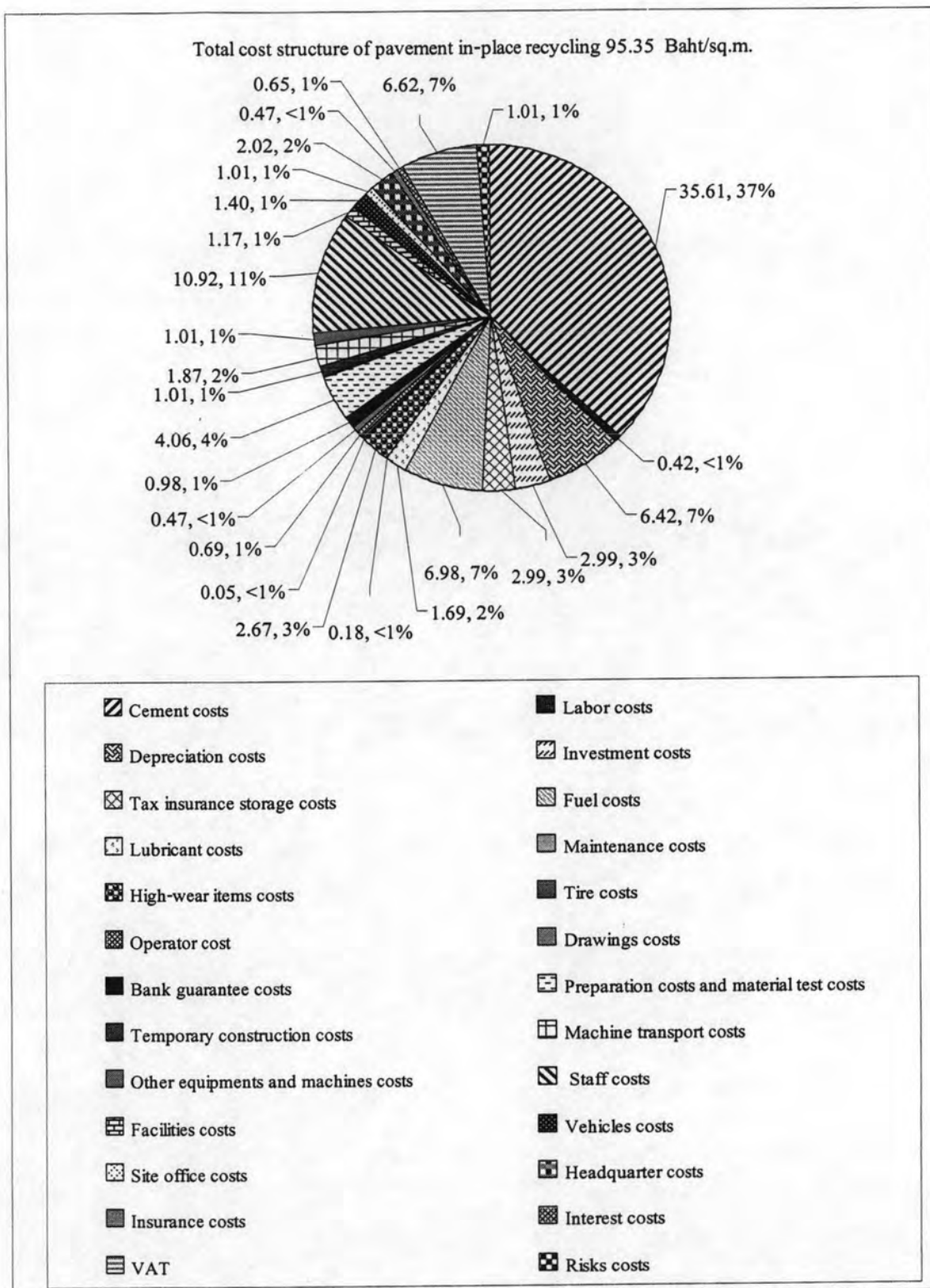
Total cost structure of pavement in-place recycling 95.35 Baht/sq.m.

0.65, 1%
0.47, <1%
2.02, 2%
1.01, 1%
1.40, 1%
1.17, 1%
10.92, 11%
1.01, 1%
1.87, 2%
1.01, 1%
4.06, 4%
0.98, 1%
0.47, <1%
0.69, 1%
0.05, <1%
2.67, 3%
0.18, <1%
1.69, 2%
6.98, 7%
2.99, 3%
2.99, 3%
6.42, 7%
0.42, <1%
35.61, 37%
1.01, 1%
6.62, 7%

Cement costs	Labor costs
Depreciation costs	Investment costs
Tax insurance storage costs	Fuel costs
Lubricant costs	Maintenance costs
High-wear items costs	Tire costs
Operator cost	Drawings costs
Bank guarantee costs	Preparation costs and material test costs
Temporary construction costs	Machine transport costs
Other equipments and machines costs	Staff costs
Facilities costs	Vehicles costs
Site office costs	Headquarter costs
Insurance costs	Interest costs
VAT	Risks costs

Figure 3.26 Total costs structure of pavement in-place recycling of the contractor in the example project of DOR

3.3 Chapter conclusion

Total costs of pavement in-place recycling of DOH & DOR can be divided into 2 parts that are comprised of direct costs and operation costs. The costs affecting direct costs can find from pavement in-place recycling formula that consist of 20 costs: investment costs, tire costs, maintenance costs, operator costs, fuel costs, lubricant costs, labor costs, depreciation costs, cement costs, and traffic factor. The costs affecting operation costs can find from Factor F that consist of 9 costs: contracting costs, site office costs, vehicles costs, staff cost, headquarter costs, risks cost, interest costs, profit, and VAT. If pavement in-place recycling project is in rainy area, there are addition 3 costs that consist of addition administrative costs, addition risks costs, and addition interest costs.

Total costs of pavement in-place recycling of the contractor can be divided into 2 parts that are comprised of direct costs and indirect costs. The costs affecting direct costs consist of 11 costs: cement costs, depreciation costs, investment costs, tax insurance and storage costs, fuel costs, lubricant costs, maintenance costs, high-wear items cost, tire costs, and operator costs. The costs affecting indirect costs consist of 11 costs: bank guarantee costs, preparation costs and material test costs, temporary construction costs, machine transport costs, other equipments and machines costs, staff costs, facilities costs, vehicles costs, site office costs, headquarter costs, insurance costs, interest costs, VAT, and risks costs.

From analysis of factors affecting total costs of pavement in-place recycling of DOH & DOR and analysis of factors affecting total costs of the contractor in the example projects of DOH & DOR, We can find the causes of difference between total costs structure of DOH & DOR and total costs structure of the contractor that will be described in next chapter.