

CHAPTER IV

RESULTS AND DISCUSSION

In this chapter, we can illustrate factors affecting total costs of pavement in-place recycling of DOH & DOR and factors affecting total costs of pavement in-place recycling of the contractor. Next, we will find the factors being cause of difference between costs in total costs of DOH & DOR and costs in total costs of the contractor. Finally, we will discuss guidelines for improving total costs estimation in pavement in-place recycling of DOH & DOR.

4.1 Factors Affecting Costs of Pavement In-Place Recycling

From analysis of factors affecting costs of pavement in-place recycling in example projects of DOH & DOR, we can find the following:

4.1.1 Factors Affecting Total costs of Pavement In-Place Recycling of DOH & DOR

The costs in total costs of pavement in-place recycling of DOH & DOR can be identified in main costs that consist of material costs, labor and machine costs, operation costs, profit, and VAT as shown in Table 4.1. From table, we can illustrate factors affecting costs as follows:

Material costs: There are only cement costs in material costs. Factors affecting cement costs consist of cement prices at factory, delivery distance, loading costs, and amount of cement.

Labor and machine costs: These main costs consist of investment costs, tire costs, maintenance costs, operator costs, fuel cost, lubricant costs, labor costs, and depreciation costs. Each costs can be illustrated as follows:

Investment costs: Factors affecting investment costs consist of new machine prices, salvage value, useful life 6 years, interest rate 7%, insurance rate 3%, type and numbers of machine.

Tire costs: Factors affecting tire costs consist of new tire prices, useful life, type and numbers of tire machine.

Maintenance costs: Factors affecting maintenance costs consist of new machine prices and repair factor, type and numbers of machine.

Operator costs: Factors affecting operator costs consist of operator wage and numbers of laborer.

Fuel costs: Factors affecting fuel costs consist of fuel prices and engine power (HP).

Lubricant costs: Factors affecting lubricant costs is fuel prices.

Labor costs: Factors affecting labor costs consist of labor wage and numbers of laborer.

Depreciation costs: Factors affecting depreciation costs consist of new machine prices, salvage value, useful life, and weather condition (normal/rainy)

In addition, operating variables e.g. operating hour 8 hours/day, machine working 3.5 hours/day, recycling depth 20 cm., and operating rate 2,520 m²/day are also affect labor and machine costs

Operation costs: These main costs consist of contracting costs, site office and vehicles costs, staff and headquarter costs, risks costs, interest costs, and addition costs for rainy. Each costs can be illustrated as follows:

Contracting costs: Factors affecting depreciation costs consist of performance bond fee 2.5% of project costs, guarantee bond fee 0.25% of direct costs, stamp duty 0.10% of direct costs, and compensation fund and social insurance fund 0.2580% of direct costs.

Site office and vehicles costs: Costs affecting site office and vehicles costs consist of site office costs and vehicles costs.

Staff and headquarter costs: Costs affecting staff and headquarter costs consist of staff costs and headquarter costs.

Risks costs: Costs affecting risks costs consists of insurance costs 0.25% of direct costs and other risks costs 0.05% of direct costs.

Interest costs: Factors affecting interest costs consist of interest rate 7%, advance payment 15%, retention money for DOH 10% and DOR 0%, time of project.

Addition costs for rainy: Costs affecting addition costs for rainy consist of addition administrative costs, addition risks costs, and addition interest costs.

In addition, quantity of work and time of project are also affect operation costs.

Profit: Profit in total costs estimation is defined as 5.50% of direct costs.

VAT: VAT in total costs estimation is defined as 7% of total costs.

Table 4.1 Factors affecting total costs of pavement in-place recycling of DOH & DOR

Main costs	Costs	Factor affecting costs
Material costs	Cement costs	Cement prices at factory Delivery distance Loading costs Amount of cement (%) DOH 4%, DOR 3.5%
Labor and machine costs	Investment costs	New machine prices Salvage value useful life Interest rate 7% Insurance rate 3% Type and numbers of machine
	Tire costs	New tire prices Tire useful life
	Maintenance costs	New machine prices Repair Factor
	Operator costs	Operator wage Numbers of worker
	Fuel costs	Fuel prices Engine power (1,111 HP)
	Lubricant costs	Fuel prices
	Labor costs	Labor wage Numbers of laborer
	Depreciation costs	New machine prices Salvage value Machine useful life Weather condition (normal/rainy)
		Operating variables Operating hour 8 hours/day Machine working 3.5 hours/day Recycling depth 20 cm. Operating rate 2,520 m ² /day

Table 4.1 Factors affecting total costs of pavement in-place recycling of DOH & DOR (con.)

Main costs	Costs	Factor affecting costs
Operation costs	Contracting costs	Performance bond fee 2.5% of project costs Guarantee bond fee 0.25% of direct costs Stamp duty 0.10% of direct costs Compensation fund and social insurance fund 0.2580% of direct costs
	Site office and vehicles costs	Site office costs Vehicles costs
	Staff and headquarter costs	Staff costs Headquarter costs
	Risks costs	Insurance costs 0.25% of direct costs Other risks costs 0.05% of direct costs
	Interest costs	Interest rate 7% Advance payment 15% Retention money DOH 10%, DOR 0% Time of project
	Addition costs for rainy	Addition administrative costs Addition risks costs Addition interest costs
		Quantity of work Time of project
Profit	Profit	5.50% of direct costs
VAT	VAT	7% of total costs

4.1.2 Factors Affecting Total costs of Pavement In-Place Recycling of the Contractor

The costs in total costs of pavement in-place recycling of the contractor can be identified in main costs that consist of material costs, labor and machine costs, operation costs, profit, and VAT as shown in Table 4.2. From table, we can illustrate factors affecting costs as follows:

Material costs: There are only cement costs in material costs. Factors affecting cement costs consist of cement prices at provinces, and amount of cement.

Labor and machine costs: This main costs consist of labor costs, depreciation costs, investment costs, tax, insurance, and storage costs, fuel costs, lubricant costs, maintenance costs, high-wear items costs, tire costs, operator costs. Each costs can be illustrated as follows:

Labor costs: Factors affecting labor costs consist of labor wage and numbers of laborer.

Depreciation costs: Factors affecting depreciation costs consist of new machine prices, salvage value, and useful life.

Investment costs: Factors affecting investment costs consist of new machine prices, interest rate 7%, type and numbers of machine.

Tax, insurance, and storage costs: Factors affecting investment costs consist of tax 1%, Insurance rate 3%, and Storage costs 3% of new machine prices.

Fuel costs: Factors affecting fuel costs consist of fuel prices and engine power (HP).

Lubricant costs: Factors affecting lubricant costs consist of lubricant, hydraulic oil, and filter costs

Maintenance costs: Factors affecting maintenance costs consist of new machine prices, salvage value, useful life, and percent of repair 50%.

High-wear items costs: Costs affecting maintenance costs consist of cutting tool costs and blade costs.

Tire costs: Factors affecting tire costs consist of new tire prices, tire useful life, type and numbers of tire machine.

Operator costs: Factors affecting operator costs consist of operator wage and numbers of worker.

In addition, operating variables e.g. operating hour 8 hours/day, machine working 8 hours/day, recycling depth 20 cm, and operating rate 3,500 m²/day are also affect labor and machine costs

Operation costs: These main costs consist of 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, and risks costs. Each costs can be illustrated as follows:

Drawings costs: Factor affecting drawings costs is drawing prices that are about 10,000 Baht/project.

Bank guarantee costs: Costs affecting bank guarantee costs consist of bid bond fee, performance bond fee, advanced payment bond fee, guarantee bond fee, and stamp duty.

Preparation costs and material test costs: Factors affecting preparation costs and material test costs are DOH material test costs rate and numbers of sample.

Temporary construction costs: Factor affecting Temporary construction costs is size of usage area.

Machine transport costs: Factor affecting machine transport costs is lump sum prices 20,000 Baht/flight

Other equipments and machines costs: Factor affecting other equipments and machines costs is the estimation at 1% of direct costs.

Staff costs: Factors affecting staff costs consist of staff salary and wage.

Facilities costs: Costs affecting facilities costs consist of electricity costs, water costs, and telephone costs.

Vehicles costs: Factor affecting vehicles costs is the estimation by lump sum 30,000 prices Baht/month.

Site office costs: Factor affecting site office costs is the estimation at 1% of direct costs.

Headquarter costs: Factor affecting headquarters costs is the estimation at 2% of direct costs.

Insurance costs: Factor affecting insurance costs is the estimation at 0.4% of insurance value.

Interest costs: Factors affecting interest costs consist of interest rate 7%, advance payment 15%, retention money, and time of project.

Risks costs: Factor affecting risks costs is the estimation at 1% of direct costs.

In addition, quantity of work and time of project are also affecting operation costs.

Profit: The amount of money remains from divided project prices by total costs.

VAT: VAT in total costs estimation is defined as 7% of total costs.

Table 4.2 Factors affecting total costs of pavement in-place recycling of the contractor

Main costs	Costs	Factor affecting costs
Material costs	Cement costs	Cement prices at province Amount of cement (%)
Labor and machine costs	Labor costs	Labor wage Numbers of laborer
	Depreciation costs	New machine prices Salvage value useful life
	Investment costs	New machine prices Interest rate 7% Type and numbers of machine
	Tax, insurance, and storage costs	Tax 1%, Insurance rate 3%, Storage costs 3% of machine prices
	Fuel costs	Fuel prices Engine power (1,200 HP)
	Lubricant costs	Lubricant, hydraulic oil, and filter costs
	Maintenance costs	New machine prices Salvage value useful life Percent of repair 50%
	High-wear items costs	Cutting tool costs Blade costs
	Tire costs	New tire prices Tire useful life
	Operator costs	Operator wage Numbers of worker
		Operating variables Operating hour 8 hours/day Machine working 8 hours/day Recycling depth 20 cm. Operating rate 3,500 m ² /day

Table 4.2 Factors affecting total costs of pavement in-place recycling of the contractor (con)

Main costs	Costs	Factor affecting costs
	Drawings costs	Drawing price 10,000 Baht/project
	Bank guarantee costs	Bid bond fee Performance bond fee Advanced payment bond fee Guarantee bond fee Stamp duty.
	Preparation costs and material test costs	DOH material test costs rate Numbers of sample
	Temporary construction costs	Size of usage area
	Machine transport costs	Lump sum 20,000 Baht/flight
	Other equipments and machines costs	Estimated 1% of direct costs
	Staff costs	Staff salary and wage
	Facilities costs	Electricity costs, water costs, and telephone costs.
	Vehicles costs	Lump sum 30,000 Baht/month
	Site office costs	Estimated 1% of direct costs
	Headquarter costs	Estimated 2% of direct costs
	Insurance costs	0.4% of insurance value
	Interest costs	Interest rate 7% Advance payment 15% Retention money Time of project
	Risks costs	Estimated 1% of direct costs
		Quantity of work Time of project
Profit	Profit	= Project prices – Total costs
VAT	VAT	7% of total costs

4.2 Comparison between costs in total costs of pavement in-place recycling of DOH & DOR and costs in total costs of the contractor in the example projects

From total costs structure of pavement in-place recycling of DOH & DOR in 3.1.3 and 3.1.6 and total costs structure of pavement in-place recycling of the contractor in example projects of DOH & DOR in 3.2.3 and 3.2.6, we can compare them to find the different between costs in these total costs as the following:

4.2.1 The difference between costs in total costs of pavement In-place recycling and costs in total costs of the contractor in the example project of DOH

To compare the different between costs in total costs of DOH and costs in total costs of the contractor, we can define contract prices are equal to total costs of DOH that are 119.32 Baht/m². From total costs of the contractor in the example project are 110.54 Baht/m², so the profit of the contractor is equal to $119.32 - 110.54 = 8.78$ Baht/m². We can compare the costs in total costs by identifying these costs into main costs that consist of material costs, labor and machine costs, operation costs, profit, and VAT as shown in Table 4.3 and Figure 4.1.

Main costs structure of pavement in-place recycling in the example project of DOH can be shown in Figure 4.2. The total costs that are 119.32 Baht/m² consist of material costs 46.78 Baht/m², labor and machine costs 46.05 Baht/m², operation costs 13.58 Baht/m², profit 5.10 Baht/m², and VAT 7.81 Baht/m². From the figure, we can see that the largest proportion of costs is material costs 39% and then labor and machine costs 39%, operation costs 11%, VAT 7% and profit 4% respectively.

Main costs structure of pavement in-place recycling of the contractor in the example project of DOH can be shown in Figure 4.3. The total costs & profit that are 119.32 Baht/m² consist of material costs 50.90 Baht/m², labor and machine costs 26.18 Baht/m², operation costs 25.67 Baht/m², profit 8.78 Baht/m², and VAT 7.79 Baht/m². From the figure, we can see that the largest proportion of costs is material costs 42% and then labor and machine costs 22%, operation costs 22%, VAT 7% and profit 7% respectively.

Table 4.3 Comparison between costs in total costs of pavement in-place recycling and costs in totals cost & profit of the contractor in an example project of DOH

Main costs	Total costs of DOH		Total costs & profit of the contractor		
	Costs	Unit prices (Baht/m ²)	Costs	Unit prices (Baht/m ²)	
Material costs	Cement costs	46.78	Cement costs	50.90	
Labor and machine costs	Investment costs	4.70	Investment costs + Tax, insurance, and storage costs	5.98	
	Tire costs	0.28	Tire costs	0.05	
	Maintenance costs	17.69	Maintenance costs + High-wear items costs	2.85	
	Operator costs	0.79	Operator costs	0.69	
	Fuel costs	4.55	Fuel costs	8.08	
	Lubricant costs	0.68	Lubricant costs	1.68	
	Labor costs	0.60	Labor costs	0.43	
	Depreciation costs	16.76	Depreciation costs	6.42	
		Total	46.05	Total	26.18
	Operation costs	Contracting costs (consists of performance bond fee, guarantee bond fee, stamp duty fee, social insurance fund)	0.67	Contracting costs (consists of drawings costs, bid bond fee, performance bond fee, advanced payment bond fee, guarantee bond fee, and stamp fee)	1.53

Table 4.3 Comparison between costs in total costs of pavement in-place recycling and costs in total costs & profit of the contractor in an example project of DOH (con)

Main costs	Total costs of DOH		Total costs & profit of the contractor	
	Costs	Unit prices (Baht/m ²)	Costs	Unit prices (Baht/m ²)
Operation costs	Site office and vehicles costs (consists of site office costs and vehicles costs)	4.69	Site office and vehicles costs (consists of preparation costs and material test costs, temporary construction costs, machine transport costs, other equipments and machines costs facilities costs, vehicles costs, site office costs)	10.33
	Staff and headquarter costs (consists of staff costs and headquarter costs)	5.27	Staff and headquarter costs (consists of staff costs, headquarter costs)	11.25
	Risks costs	1.62	Risks costs (consists of insurance costs, risks costs)	1.57
	Interest costs	1.33	Interest costs	0.99
	Total	13.58	Total	25.67
Profit	Profit	5.10	Profit	8.78
VAT	VAT	7.81	VAT	7.79
	Total costs	119.32	Total costs & profit	119.32

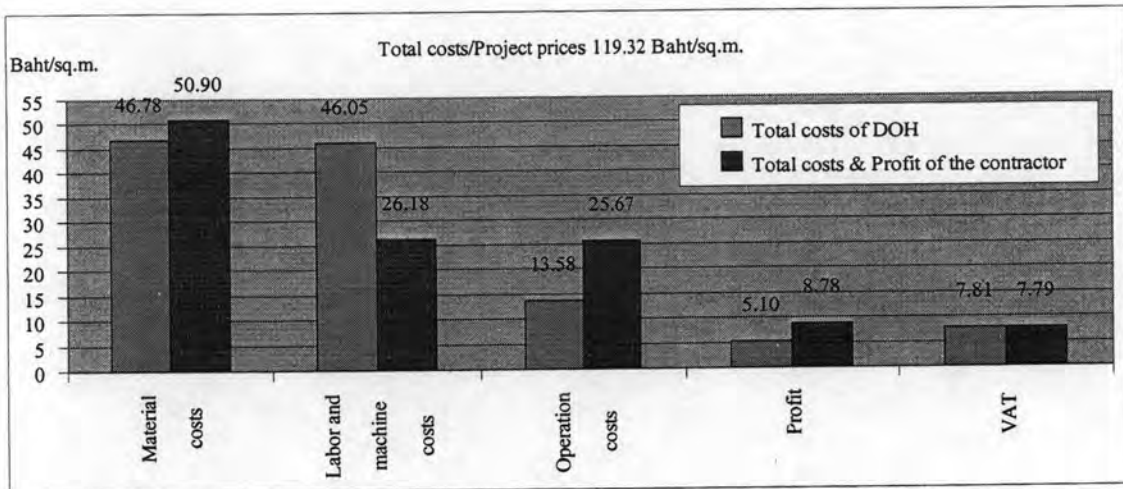


Figure 4.1 Comparison costs in main costs between DOH and the contractor.

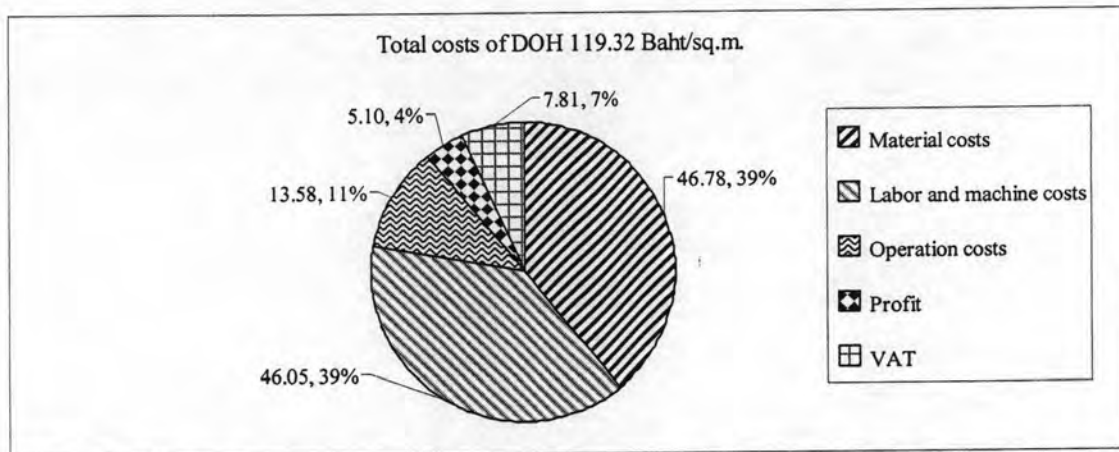


Figure 4.2 Main costs structure of pavement in-place recycling in the example project of DOH

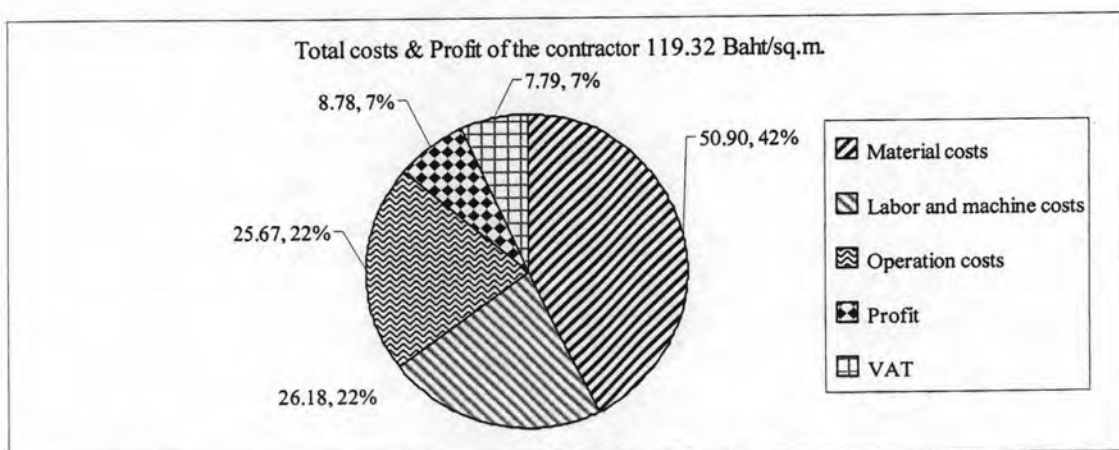


Figure 4.3 Main costs structure of pavement in-place recycling of the contractor in the example project of DOH

4.2.2 The difference between costs in total costs of pavement In-place recycling and costs in total costs of the contractor in the example project of DOR

To compare the different between costs in total costs of DOR and costs in total costs of the contractor, we can define contract prices are equal to total costs of DOR that are 101.17 Baht/m². From total costs of the contractor in the example project are 95.35 Baht/m², so the profit of the contractor is equal to $101.17 - 95.35 = 5.82$ Baht/m². We can compare the costs in total costs by identifying these costs into main costs that consist of material costs, labor and machine costs, operation costs, profit, and VAT as shown in Table 4.4 and Figure 4.4.

Main costs structure of pavement in-place recycling in the example project of DOR can be shown in Figure 4.5. The total costs that are 101.17 Baht/m² consist of material costs 35.12 Baht/m², labor and machine costs 42.92 Baht/m², operation costs 12.21 Baht/m², profit 4.29 Baht/m², and VAT 6.63 Baht/m². From the figure, we can see that the largest proportion of costs is labor and machine costs 42% and then material costs 35%, operation costs 12%, VAT 7% and profit 4% respectively.

Main costs structure of pavement in-place recycling of the contractor in the example project of DOR can be shown in Figure 4.6. The total costs & profit that are 101.17 Baht/m² consist of material costs 35.61 Baht/m², labor and machine costs 25.08 Baht/m², operation costs 28.05 Baht/m², profit 5.82 Baht/m², and VAT 6.62 Baht/m². From the figure, we can see that the largest proportion of costs is material costs 34% and then labor and machine costs 28%, operation costs 25%, VAT 7% and profit 6% respectively.

Table 4.4 Comparison between costs in total costs of pavement in-place recycling and costs in total costs & profit of the contractor in an example project of DOR

Main costs	Total costs of DOR		Total costs & profit of the contractor	
	Costs	Unit prices (Baht/m ²)	Costs	Unit prices (Baht/m ²)
Material costs	Cement costs	35.12	Cement costs	35.61
Labor and machine costs	Investment costs	4.70	Investment costs + Tax, insurance, and storage costs	5.98
	Tire costs	0.28	Tire costs	0.05
	Maintenance costs	17.69	Maintenance costs + High-wear items costs	2.85
	Operator costs	0.79	Operator costs	0.69
	Fuel costs	3.93	Fuel costs	6.98
	Lubricant costs	0.59	Lubricant costs	1.68
	Labor costs	0.60	Labor costs	0.42
	Depreciation costs	13.41	Depreciation costs	6.42
	Traffic Factor	0.93		
		Total	42.92	Total
Operation costs	Contracting costs (consists of performance bond fee, guarantee bond fee, stamp duty fee, social insurance fund)	0.54	Contracting costs (consists of drawings costs, bid bond fee, performance bond fee, advanced payment bond fee, guarantee bond fee, and stamp fee)	1.45

Table 4.4 Comparison between costs in total costs of pavement in-place recycling and costs in total cost & profit of the contractor in an example project of DOR (con)

Main costs	Total cost of DOR		Total cost & profit of the contractor	
	Costs	Unit prices (Baht/m ²)	Costs	Unit prices (Baht/m ²)
Operation costs	Site office and vehicles costs (consists of site office costs and vehicles costs)	5.16	Site office and vehicles costs (consists of preparation costs and material test costs, temporary construction costs, machine transport costs, other equipments and machines costs facilities costs, vehicles costs, site office costs)	11.53
	Staff and headquarter costs (consists of staff costs and headquarter costs)	5.76	Staff and headquarter costs (consists of staff costs, headquarter costs)	12.94
	Risks costs	0.23	Risks costs (consists of insurance costs, risks costs)	1.48
	Interest costs	0.52	Interest costs	0.65
	Total	12.21	Total	28.05
Profit	Profit	4.29	Profit	5.82
VAT	VAT	6.63	VAT	6.62
	Total costs	101.17	Total costs & profit	101.17

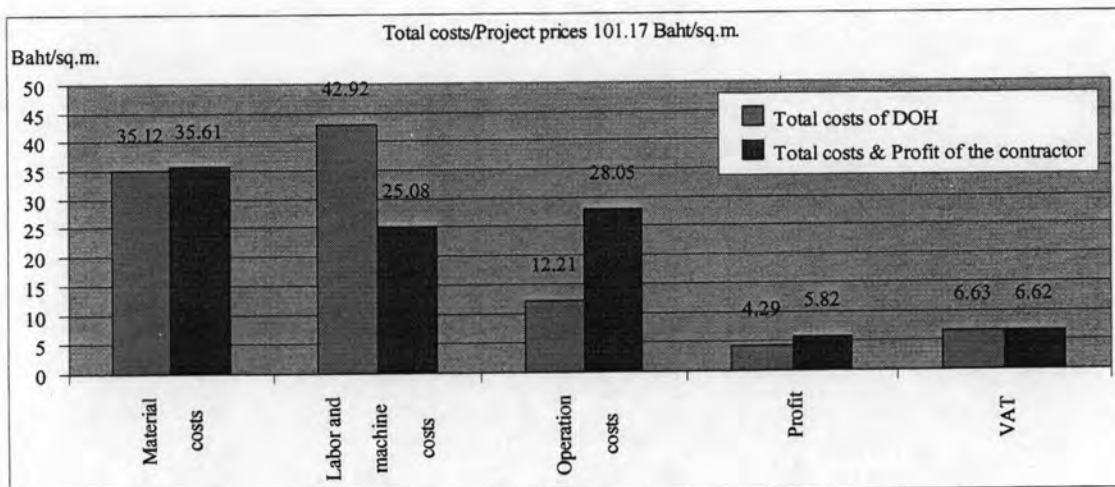


Figure 4.4 Comparison costs in main costs between DOR and the contractor

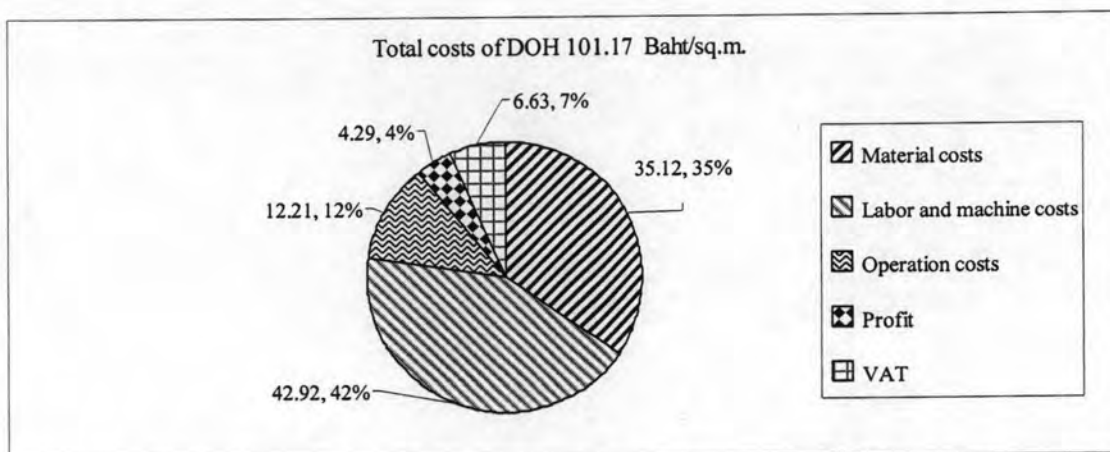


Figure 4.5 Main costs structure of pavement in-place recycling in the example project of DOR

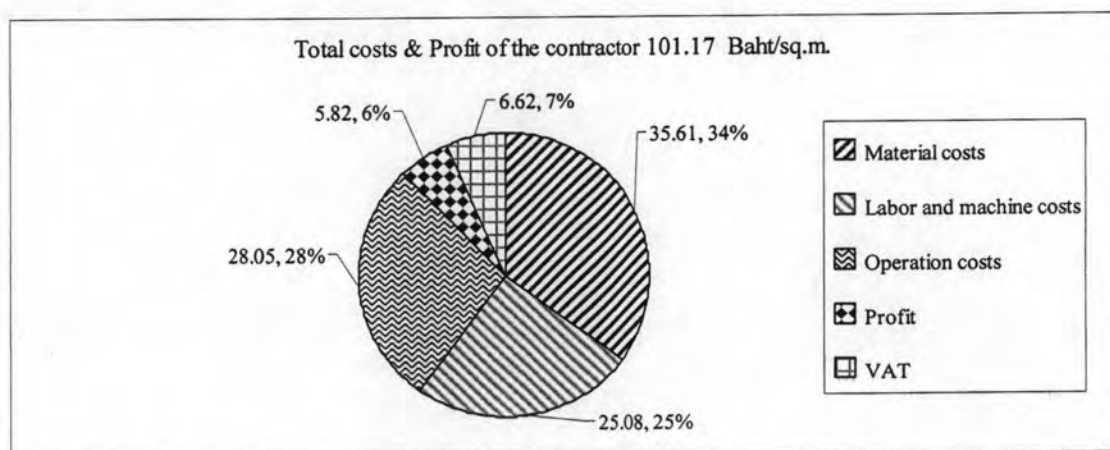


Figure 4.6 Main costs structure of pavement in-place recycling of the contractor in the example project of DOR

4.3 Factors Being Cause of Difference between Costs in Total costs of DOH & DOR, and Costs in Total costs of the Contractor

From the result of comparison between costs of DOH & DOR and costs of the contractor in example projects in 4.2, we can discuss the factors being cause of difference between costs in total costs of DOH & DOR and costs in total costs of the contractor as following:

4.3.1 Factors Being Cause of Difference between Costs in Total costs of DOH and Costs in Total costs of the Contractor

From the result of costs comparison in example project of DOH as shown in Figure 4.1 – 4.3 and Table 4.1, we can find some factors being cause of difference in total costs of DOH and in total costs of the contractor. These factors can be discussed in each main costs as follows:

Material costs: cement costs in total costs of DOH are 46.78 Baht/m² or 39% of total costs, while the cement costs in total costs of contractor are 50.90 Baht/m² or 42% of total costs (contract prices). The cause of difference comes from the different sources of cement prices used for estimation. DOH uses cement prices from wholesale prices for the contractor (not included VAT) at a cement factory near construction site. For this example project, wholesale prices of cement at factory in November 2007 is 2,194 Baht/ton plus delivery costs for 234 km. 299.39 Baht/ton and plus loading costs 50 Baht/ton that is equal 2,543.39 Baht/ton. The contractor uses cement prices from province prices by commercial ministry. For this example project, wholesale prices of cement at Stun province in December 2007 is 2,766.35 Baht/ton. The cement price of the contractor in this example project is more than cement prices of DOH about 222.95 Baht/ton. We can find that the cause of difference in cement costs is source of cement prices data that used for estimation.

Labor and machine costs: labor and machine costs of DOH are 46.05 Baht/m² or 39% of total costs, while labor and machine costs of the contractor are 26.18 Baht/m² or 22% of total costs (contract prices). The costs of DOH are more than the contractor about 19.87 Baht/m² or 17%. When we consider costs being cause of difference in labor and machine costs, we can find the following:

Investment costs: investment costs of DOH (machine operation costs/fixed costs/investment costs) are 4.70 Baht/m², while investment costs of the contractor (machine costs/pavement in-place recycling machine costs/ownership costs/ investment costs) + (machine costs/vibrating roller costs/ownership costs/ investment costs) are $2.72 + 0.27 = 2.99$ Baht/m². DOH uses machine prices as follows: cold recycler 48,384,000 Baht, steel wheel compact 3,500,000 Baht, rubber tire roller 3,200,000 Baht, cement truck 2,250,133 Baht and water truck 2,300,000 Baht. The total machine prices are 59,634,133 Baht. The contractor can use machine prices from sale agency. For this example project, machine prices in April 2008 as shown in Table 3.16 that consist of: cold recycler with cement spreader unit 34,000,000 Baht and vibrating roller 3,400,000 Baht. The total machine price is 37,400,000 Baht. The total machine prices of DOH are more than the contractor 22,234,133 Baht. We can find that cause of difference is machine prices, type, and numbers of machines used for estimation. In addition, operating rate of DOH is 2,520 m²/day, while operating rate of the contractor is 3,500 m²/day, which also is another cause of difference.

Tire costs: tire costs of DOH (machine operation costs/fixed costs/tire costs) are 0.28 Baht/m², while tire costs of the contractor (machine costs/pavement in-place recycling machine costs/tire costs) are 0.05 Baht/m². The tire costs of DOH are more than the contractor 0.23 Baht/m². We can find that cause of difference is type and numbers of machines with tire that used for estimation.

Maintenance costs: maintenance costs of DOH (machine operation costs/fixed costs/ maintenance costs) are 17.69 Baht/m², while maintenance costs and high-wears item costs of the contractor (machine costs/pavement in-place recycling machine costs/operating costs/maintenance costs and high-wears item costs) + (machine costs/vibrating roller costs/operating costs/maintenance costs and high-wears item costs) are $0.14 + 2.67 + 0.04 = 2.85$ Baht/m². The maintenance costs of DOH are much more than the contractor 14.84 Baht/m². We can find that cause of difference is different maintenance costs estimation method between DOH and the contractor.

Operator costs: operator costs of DOH (machine operation costs/fixed costs/operator costs) are 0.79 Baht/m², while operator costs of the contractor (machine costs/pavement in-place recycling machine costs/operating costs/operator costs) + (machine costs/vibrating roller costs/operating costs/operator costs) are $0.46 + 0.23 = 0.69$ Baht/m². The operator costs of DOH are more than the contractor 0.10 Baht/m². We can find that causes of difference are machine driver wage, numbers of drivers, and operating rate.

Fuel costs: fuel costs of DOH (machine operation costs/operating costs/operator costs) are 4.55 Baht/m², while fuel costs of the contractor (machine costs/pavement in-place recycling machine costs/operating costs/fuel costs) + (machine costs/vibrating roller costs/operating costs/fuel costs) are $6.54 + 1.54 = 8.08$ Baht/m². The operator costs of the contractor are more than DOH 3.53 Baht/m². DOH uses machines as follows: cold recycler 601 HP, steel wheel compact 130 HP, rubber tire roller 80 HP, cement truck 150 HP and water truck 150 HP. The total machine power is 1,111 HP. The contractor can uses machines as follows: cold recycler with spreader unit 860 HP, steel wheel compact 150 HP, rubber tire roller 190 HP. The total machine power is 1,200 HP. We can find that causes of difference are type and numbers of machines, machine power, operating condition, operating time, and operating rate.

Lubricant costs: lubricant costs of DOH (machine operation costs/operating costs/ lubricant costs) are 0.68 Baht/m², while lubricant costs of the contractor (machine costs/pavement in-place recycling machine costs/operating costs/lubricant costs) + (machine costs/vibrating roller costs/operating costs/ lubricant costs) are $1.24 + 0.44 = 1.68$ Baht/m². The lubricant costs of the contractor are more than DOH 1.00 Baht/m². We can find that cause of difference is different lubricant costs estimation method between DOH and the contractor. DOH uses relation between fuel costs to find lubricant costs, but the contractor can use record from machine manufacturer.

Labor costs: labor costs of DOH are 0.60 Baht/m², while labor costs of the contractor are 0.43 Baht/m². DOH uses minimum daily wage 149.36 Baht /day and 10 laborers for labor costs estimation that is not different from the contractor that can use minimum daily wage at Stun province 150.00 Baht/day and 10 laborers.

Depreciation costs: depreciation costs of DOH are 16.76 Baht/m², while depreciation costs of the contractor (machine costs/pavement in-place recycling machine costs/ownership costs/depreciation costs) + (machine costs/vibrating roller costs/ownership costs/depreciation costs) are $5.84 + 0.58 = 6.42$ Baht/m². The depreciation costs of DOH are much more than the contractor 10.34 Baht/m². We can find that causes of difference are type and numbers of machine, new machine prices, useful life, interest rate, and operating rate. In addition, DOH has addition depreciation costs for rainy condition up to 25% from normal rain condition that is also another cause of difference.

Operation cost: operation costs of DOH are 13.58 Baht/m² or 11% of total costs, while operation costs of the contractor are 25.67 Baht/m² or 22% of total costs (contract prices). The costs of the contractor are more than DOH about 19.87 Baht/m² or 17%. When we consider costs being cause of difference in operation costs, we can find the following:

Contracting costs: contracting costs of DOH that are 0.67 Baht/m² consist of performance bond fee 0.10 Baht/m², guarantee bond fee 0.23 Baht/m², stamp duty 0.10 Baht/m², and compensation fund and social insurance fund 0.24 Baht/m², while contracting costs of the contractor that are 1.53 Baht/m² consist of drawings costs 0.38 Baht/m², bank guarantee costs 1.15 Baht/m². The costs of the contractor are more than DOH about 0.86 Baht/m². We can find that DOH calculates contracting costs from percentage of direct costs, while the contractor calculates contracting costs from percentage of total costs (contract prices). That is the cause of difference

Site office and vehicles costs: site office and vehicles costs of DOH that are 4.69 Baht/m² consist of site office costs 1.00 Baht/m² and vehicles costs 3.69 Baht/m², while site office and vehicles costs of the contractor that are 10.33 Baht/m² consist of preparation costs and material test costs 3.58 Baht/m², temporary construction costs 0.68 Baht/m², machine transport costs 1.52 Baht/m², other equipments and machines costs 1.19 Baht/m², facilities costs 1.03 Baht/m², vehicles costs 1.14 Baht/m², site office costs 1.19 Baht/m². The costs of the contractor are more than DOH about 5.64 Baht/m². We can find that DOH has defined only 2 costs

in site office and vehicles costs, but the contractor can define 6 costs in site office and vehicles costs.

Staff and headquarter costs: staff and headquarter costs of DOH that are 5.27 Baht/m² consist of staff costs 3.87 Baht/m² and headquarter costs 1.40 Baht/m², while staff and headquarter costs of the contractor that are 11.25 Baht/m² consist of staff costs 8.87 Baht/m² and headquarter costs 2.38 Baht/m². The costs of the contractor are more than DOH about 5.98 Baht/m². We can find that DOH has defined administrative and control staff can operate 2 projects simultaneous, so the staff costs in this part can be calculated a half. DOH has also defined a headquarter can controls 4 projects simultaneous, so the headquarter costs can be calculated a quarter. These are the causes of difference.

Risks costs: risks costs of DOH that are 1.62 Baht/m² consist of insurance costs 0.23 Baht/m², other risks costs 0.05 Baht/m², addition risks costs for rainy case 0.58 Baht/m², and addition administrative costs for rainy case 0.76 Baht/m², while risks costs of the contractor that are 1.57 Baht/m² consist of insurance costs 0.38 Baht/m² and risks costs 1.19 Baht/m². The costs of DOH are more than the contractor about 0.05 Baht/m². We can find that DOH has defined addition risks costs and addition administrative costs for rainy case in this example project. That is the cause of difference.

Interest costs: interest costs of DOH that are 1.33 Baht/m² consist of interest costs 0.79 Baht/m² and addition interest costs 0.54 Baht/m², while interest costs of the contractor are 0.99 Baht/m². The costs of DOH are more than the contractor about 0.34 Baht/m². We can find that DOH has defined addition interest costs for rainy case in this example project that is the cause of difference.

Profit: profit of DOH is 5.10 Baht/m² or 4% of total costs, while profit of the contractor is 8.78 Baht/m² or 7% of total costs (contract prices). The profit of the contractor is more than DOH about 3.68 Baht/m² or 3% of project cost (total costs).

VAT: VAT of DOH is 7.81 Baht/m² or 7% of total costs, while VAT of the contractor is 7.79 Baht/m² or 7% of project cost (total costs). VAT of DOH is as same as the contractor.

4.3.2 Factors Being Cause of Difference between Costs in Total costs of DOR and Costs in Total costs of the Contractor

From the result of costs comparison in example project of DOR as shown in Figure 4.4 – 4.6 and Table 4.2, we can find some factors being cause of difference in total costs of DOR and in total costs of the contractor. These factors can be discussed in each main costs as follows:

Material costs: cement costs in total costs of DOR are 35.12 Baht/m² or 35% of total costs, while the cement costs in total costs of contractor are 35.61 Baht/m² or 35% of project cost (total costs). The cause of difference comes from the different sources of cement prices used for estimation. DOR uses cement prices from wholesale prices for the contractor (not included VAT) at a cement factory near construction site. For this example project, wholesale prices of cement at factory in August 2007 is 2,300 Baht/ton and delivery costs for 35 km. 41.48 Baht/ton that is equal 2,341.48 Baht/ton. The contractor uses cement prices from province prices by commercial ministry. For this example project, wholesale prices of cement at Chiang Rai province in August 2007 are 2,373.83 Baht/ton. The cement price of the contractor in this example project is more than cement prices of DOR about 32.35 Baht/ton. We can find that the cause of difference in cement costs is source of cement prices data that used for estimation.

Labor and machine costs: labor and machine costs of DOR are 42.92 Baht/m² or 42% of total costs, while labor and machine costs of the contractor are 25.08 Baht/m² or 17% of total costs (contract prices). The costs of DOR are more than the contractor about 17.84 Baht/m² or 17%. When we consider costs being cause of difference in labor and machine costs, we can find the following:

Investment costs: investment costs of DOR (machine operation costs/fixed costs/investment costs) are 4.70 Baht/m², while investment costs of the contractor (machine costs/pavement in-place recycling machine costs/ownership costs/ investment costs) + (machine costs/vibrating roller costs/ownership costs/ investment costs) are $2.72 + 0.27 = 2.99$ Baht/m². DOR uses machine prices as follows: cold recycler 48,384,000 Baht, steel wheel compact 3,500,000 Baht, rubber tire roller 3,200,000 Baht, cement truck 2,250,133 Baht and

water truck 2,300,000 Baht. The total machine prices are 59,634,133 Baht. The contractor can use machine prices from sale agency. For this example project, machine prices in April 2008 as shown in Table 3.16 that consist of: cold recycler with cement spreader unit 34,000,000 Baht and vibrating roller 3,400,000 Baht. The total machine price is 37,400,000 Baht. The total machine prices of DOR are more than the contractor 22,234,133 Baht. We can find that cause of difference is machine prices, type, and numbers of machines used for estimation. In addition, operating rate of DOR is 2,520 m²/day, while operating rate of the contractor is 3,500 m²/day, which also is another cause of difference.

Tire costs: tire costs of DOR (machine operation costs/fixed costs/tire costs) are 0.28 Baht/m², while tire costs of the contractor (machine costs/pavement in-place recycling machine costs/tire costs) are 0.05 Baht/m². The tire costs of DOR are more than the contractor 0.23 Baht/m². We can find that cause of difference is type and numbers of machines with tire that used for estimation.

Maintenance costs: maintenance costs of DOR (machine operation costs/fixed costs/ maintenance costs) are 17.69 Baht/m², while maintenance costs and high-wears item costs of the contractor (machine costs/pavement in-place recycling machine costs/operating costs/maintenance costs and high-wears item costs) + (machine costs/vibrating roller costs/operating costs/maintenance costs and high-wears item costs) are 0.14 + 2.67 + 0.04 = 2.85 Baht/m². The maintenance costs of DOR are much more than the contractor 14.84 Baht/m². We can find that cause of difference is different maintenance costs estimation method between DOR and the contractor.

Operator costs: operator costs of DOR (machine operation costs/fixed costs/operator costs) are 0.79 Baht/m², while operator costs of the contractor (machine costs/pavement in-place recycling machine costs/operating costs/operator costs) + (machine costs/vibrating roller costs/operating costs/ operator costs) are 0.46 + 0.23 = 0.69 Baht/m². The operator costs of DOR are more than the contractor 0.10 Baht/m². We can find that causes of difference are machine driver wage, numbers of drivers, and operating rate.

Fuel costs: fuel costs of DOR (machine operation costs/operating costs/operator costs) are 3.93 Baht/m², while fuel costs of the contractor (machine costs/pavement in-place recycling machine costs/operating costs/fuel costs) + (machine costs/vibrating roller costs/operating costs/fuel costs) are 5.64 + 1.34 = 6.98 Baht/m². The operator costs of the contractor are more than DOR 3.05 Baht/m². DOR uses machines as follows: cold recycler 601 HP, steel wheel compact 130 HP, rubber tire roller 80 HP, cement truck 150 HP and water truck 150 HP. The total machine power is 1,111 HP. The contractor can use machines as follows: cold recycler with spreader unit 860 HP, steel wheel compact 150 HP, rubber tire roller 190 HP. The total machine power is 1,200 HP. We can find that causes of difference are type and numbers of machines, machine power, operating condition, operating time, and operating rate.

Lubricant costs: lubricant costs of DOR (machine operation costs/operating costs/ lubricant costs) are 0.59 Baht/m², while lubricant costs of the contractor (machine costs/pavement in-place recycling machine costs/operating costs/ lubricant costs) + (machine costs/vibrating roller costs/operating costs/ lubricant costs) are 1.25 + 0.44 = 1.69 Baht/m². The lubricant costs of the contractor are more than DOR 1.10 Baht/m². We can find that cause of difference is different lubricant costs estimation method between DOR and the contractor. DOR uses relation between fuel costs to find lubricant costs, but the contractor can use record from machine manufacturer.

Labor costs: labor costs of DOR are 0.60 Baht/m², while labor costs of the contractor are 0.43 Baht/m². DOR uses minimum daily wage 149.36 Baht /day and 10 laborers for labor costs estimation that is not different from the contractor that can use minimum daily wage at Chiang Rai province 146.00 Baht/day and 10 laborers.

Depreciation costs: depreciation costs of DOR are 13.41 Baht/m², while depreciation costs of the contractor (machine costs/pavement in-place recycling machine costs/ownership costs/depreciation costs) + (machine costs/vibrating roller costs/ownership costs/depreciation costs) are 5.84 + 0.58 = 6.42 Baht/m². The depreciation costs of DOR are much more than the contractor 6.99 Baht/m². We can find that cause of difference are type and numbers of machine, new machine

prices, useful life, interest rate, and operating rate. In addition, DOR has addition depreciation costs for rainy condition up to 25% from normal rain condition that is also another cause of difference.

Traffic Factor: DOR uses traffic factor in pavement in-place recycling formula for adding costs from traffic condition. For this example project, traffic factor value is 0.93 Baht/ m².

Operation cost: operation costs of DOR are 12.21 Baht/m² or 12% of total costs, while operation costs of the contractor are 28.05 Baht/m² or 28% of total costs (contract prices). The costs of the contractor are more than DOR about 15.84 Baht/m² or 16%. When we consider costs being cause of difference in operation costs, we can find the following:

Contracting costs: contracting costs of DOR that are 0.54 Baht/m² consist of performance bond fee 0.07 Baht/m², guarantee bond fee 0.20 Baht/m², stamp duty 0.07 Baht/m², and compensation fund and social insurance fund 0.20 Baht/m², while contracting costs of the contractor that are 1.45 Baht/m² consist of drawings costs 0.47 Baht/m², bank guarantee costs 0.98 Baht/m². The costs of the contractor are more than DOR about 0.91 Baht/m². We can find that DOR calculates contracting costs from percentage of direct costs, while the contractor calculates contracting costs from percentage of total costs (project prices). That is the cause of difference

Site office and vehicles costs: site office and vehicles costs of DOR that are 5.16 Baht/m² consist of site office costs 1.09 Baht/m² and vehicles costs 4.07 Baht/m², while site office and vehicles costs of the contractor that are 11.53 Baht/m² consist of preparation costs and material test costs 4.06 Baht/m², temporary construction costs 1.00 Baht/m², machine transport costs 1.87 Baht/m², other equipments and machines costs 1.01 Baht/m², facilities costs 1.17 Baht/m², vehicles costs 1.40 Baht/m², site office costs 1.01 Baht/m². The costs of the contractor are more than DOR about 6.37 Baht/m². We can find that DOR has defined only 2 costs in site office and vehicles costs, but the contractor can define 6 costs in site office and vehicles costs.

Staff and headquarter costs: staff and headquarter costs of DOR that are 5.76 Baht/m² consist of staff costs 4.21 Baht/m² and headquarter costs 1.55 Baht/m², while staff and headquarter costs of the contractor that are 12.94 Baht/m² consist of staff costs 10.92 Baht/m² and headquarter costs 2.02 Baht/m². The costs of the contractor are more than DOR about 7.18 Baht/m². We can find that DOR has defined administrative and control staff can operate 2 projects simultaneous, so the staff costs in this part can be calculated a half. DOR has also defined a headquarter can controls 4 projects simultaneous, so the headquarter costs can be calculated a quarter. These are the causes of difference.

Risks costs: risks costs of DOR that are 0.23 Baht/m² consist of insurance costs 0.20 Baht/m² and other risks costs 0.03 Baht/m², while risks costs of the contractor that are 1.48 Baht/m² consist of insurance costs 0.47 Baht/m² and risks costs 1.01 Baht/m². The costs of the contractor are more than DOR about 1.25 Baht/m².

Interest costs: interest costs of DOR that are 0.52 Baht/m², while interest costs of the contractor are 0.65 Baht/m². The costs of DOR are more than the contractor about 0.13 Baht/m².

Profit: profit of DOR is 4.29 Baht/m² or 4% of total costs, while profit of the contractor is 5.82 Baht/m² or 6% of project cost (total costs). The profit of the contractor is more than DOH about 1.53 Baht/m² or 2% of project cost (total costs).

VAT: VAT of DOR is 6.63 Baht/m² or 7% of total costs, while VAT of the contractor is 6.62 Baht/m² or 7% of project cost (total costs). VAT of DOR is as same as the contractor.

4.4 Guidelines for Improving Total costs Estimation in Pavement In-Place Recycling of DOH & DOR

Considering factors being cause of difference between costs in total costs of DOH & DOR and costs in total costs of the contractor, we can find some guidelines for improving total costs estimation of DOH & DOR in material costs, labor and machine costs, and operation costs as following:

4.4.1 Materials Costs Estimation Improvement

The major factor directly affect to costs of cement is the amount of cement that is used to mix with RAP material. The percentage of cement used in DOH projects defined as 4% and in DOR projects defined as 3.5% by weight of RAP material. We can see that both DOH & DOR use different percentage of cement and find from the tables. Therefore, the guideline for improving material costs estimation is that it should has RAP material testing to design exactly percentage of cement in admixture in each projects instead of using constant value from the tables. By this way, DOH & DOR can use the amount of cement in appropriate and the quality of work is also followed by standard. Furthermore, it's possible to find that some projects can use percentage of cement less than it used to be. That may be a way to decrease cement costs of pavement in-place recycling project.

4.4.2 Labor and Machine Costs Estimation Improvement

The costs highly affect to labor and machine costs of DOH & DOR are investment costs, depreciation costs, and maintenance cost. The factors affecting these costs are new machine prices. The prices of new cold recycler that DOH & DOR use for calculation is 48,384,000 Baht, while the present prices of pavement in-place recycling machines from sale agency is about 34,000,000. From this point, we can see the different in prices for total costs estimation is much more than 14,384,000 Bath. The type of machines that is defined for the estimation of DOH & DOR have 5 types in 5 units that are comprised of cold recycler 1 unit, steel wheel compact 1 unit, rubber tire roller 1 unit, cement truck 1 unit, and water truck 1 unit. For the real operation of the contractors, it's possible to use only 3 types in 3 units that are comprised of cold recycler with cement spreader 1 unit, steel wheel compact 1 unit, and rubber tire roller 1 unit. Therefore, the guideline for improving labor and machine

costs estimation is that DOH & DOR should update the new machine prices corresponding to real market prices. Besides, it's possible to exclude some type of machines such as cement truck and water truck from the estimation. The fuel cost is another costs affecting labor and machine costs. Factors affecting fuel costs are quantity of fuel consumption and fuel prices. The quantity of fuel consumption depends on type and numbers of machines. So cutting some type of machines will be another way to decrease fuel costs of pavement in-place recycling.

In addition, weather condition in construction area affects depreciation costs especially in rainy case that has to add depreciation costs more 25% from normal rain case. That making depreciation cost of DOH & DOR is much more than of the contractor. Generally, pavement in-place recycling use short time in operation. Therefore, the projects that can be done out of rainy season should calculate the depreciation costs in normal rain case.

4.4.3 Operation Costs Estimation Improvement

Mainly factor affecting operation costs is Factor F. The operation costs can find from multiply Factor F with direct costs. Therefore, the decreasing in direct costs can also decrease in operation costs too. Factor F for road construction has 3 cases: Factor F (normal rain), Factor F (rainy1), and Factor F (rainy2). The case of Factor F depends on weather condition in each province. DOH & DOR define the projects that are located in rainy1 or rainy2 provinces may be late for 1 to 2 months. This late from weather condition makes addition costs. The addition costs consist of addition administrative costs, addition risks costs, and addition interest costs.

Pavement in-place recycling uses short time for operation. Therefore, the guideline for improving operation costs estimation is that the projects that can be done out of rainy season should use Factor F in normal rain case. This will be one way to decrease operation costs of pavement in-place recycling. Interest costs are another costs that affect operation costs. Factors affecting interest costs consist of interest rate, advance payment, and retention money. DOH defines retention money as 10%, while DOR defines retention money as 0%. So, the decreasing retention money may be another way to decrease operation costs of pavement in-place recycling.