4 Current Status of Infrastructure Management in Thailand

4.1 Status of Aging Infrastructure and Future Forecast

Major infrastructure development in Thailand started in the 1980's including expressways whose construction started 35 years ago. As a result, fundamental industrial infrastructure such as roads, harbors and power plants have been developed more than other surrounding countries. This was an advantage of Thailand to attract foreign investment and to provide the basis for economic development.[49]

Net capital stock owned by the governmental organizations such as roads, bridges, dams, airports, office buildings and power facilities has been growing, as shown in Figure 34, reaching 11,423 billion baht in 2012.[50]

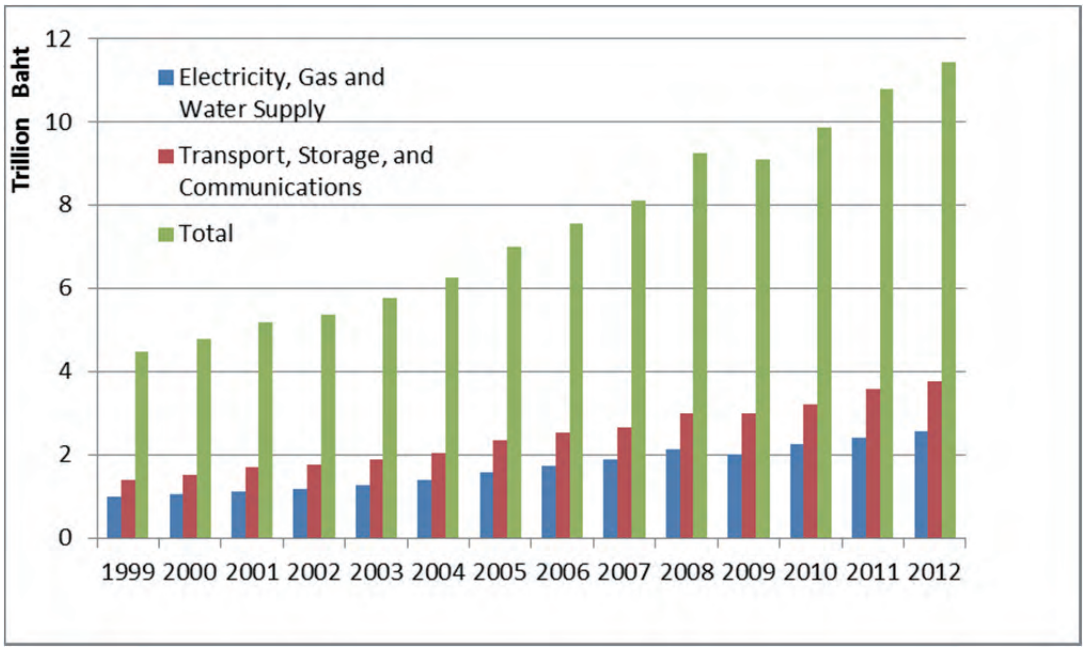


Figure 41 Trends of Net Social Capital in Public Sector (current prices)

Source: Capital Stock of Thailand, 2012 edition, NESDB

In the transport and communications sector, investment in new communications infrastructure is apparent in recent years, while a part of transportation infrastructure is getting older. The situation is similar in the railway sector, where 67% of railways of SRT are more than 30 years old.[51] For example, aging of bridges is evident: among the bridges managed by DOH, there

[49] Thailand Infrastructure Map, March 2012, JETRO Bangkok Office
[50] Capital Stock of Thailand 2012, NESDB, 2013
[51] Kingdom of Thailand: Accounting and financial Management System Reform of Thailand's Railway Sector, March 2014, ADB

are now 338 bridges which are more than 50 years old, or 2% of the total, and will be 1,818 or 12% in another 10 years.

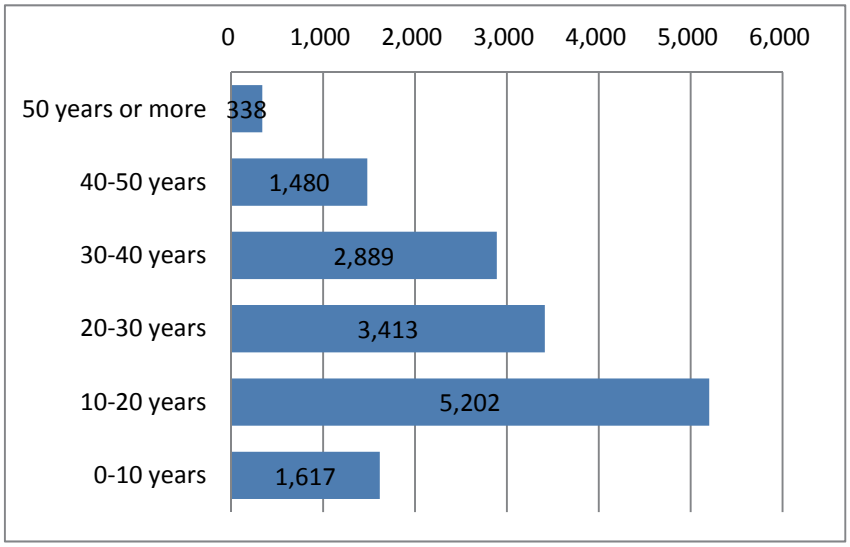


Figure 42 Number of Bridges by Age52

Source: DOH

On the other hand, Thailand is planning to develop new infrastructure facilities to consolidate its leading position in the ASEAN area in view of the formation of ASEAN Economic Community (AEC) in 2015. In 2013, the government announced a large-scale infrastructure development plan up to 2020 whose total cost amounts to more than 2 trillion baht (planned as of February 2013) to enhance the transportation infrastructure and improve the connectivity in the ASEAN region. This is comparable to the national budget, which was 2.525 trillion baht in 2014[53].

[52] ODA Project Formulation Survey on popularization of 3D maintenance method for structures by Japan's high-tech survey instruments and measurement technologies in Thailand, March 2014, JICA

[53] Funding sources of the national budget are: revenue of 2.275 billion baht and government bonds for the remaining 0.25 billion baht (Source: Thailand's Budget in Brief Fiscal Year 2014, Bureau of the Budget)

Table 29 Infrastructure Improvement Plan (2013 – 2020)

Item	Budget (Mill baht)
1. Modal Shift	354,561
1.1 Improvement of Railway System (Development of Double Tracks and Improvement of Rails)	308,338
1.2 Improvement of Water Transportation and Construction of Harbors	29,820
1.3 Construction of Truck Terminals	16,403
2. Improvement of Connectivity	1,042,377
2.1 Development of Border Gateway (Improvement of Roads and Construction of Customs Office)	47,946
2.2 Rural Network (High-Speed Railways and Expressways)	994,431
3. Improvement of Mobility	593,802
3.1 Development of Transportation in Cities (Such as Subways)	472,448
3.2 Development of Transportation between Major Economic Areas in Thailand	121,353
4. Promotional Activities for This Plan and Others	9,261
Total	2,000,000

Source: Thailand Infrastructure Map, March 2012, JETRO Bangkok Office

Next, the fund source is as follows: In Thailand, the ratio of senior citizens 65 years of age or older exceeded 7% in 2007, which means the arrival of an "aging society," and will reach 14% in 2027 when Thailand will become a "super-aging society." Thailand acknowledges the need for address issues impacting the elderly and society and established the National Committee of Senior Citizens. Therefore, it will inevitably be difficult in the future to acquire fund sources for infrastructure improvement due to slowdown of fare receipts and tax revenue and increase of welfare expenses.

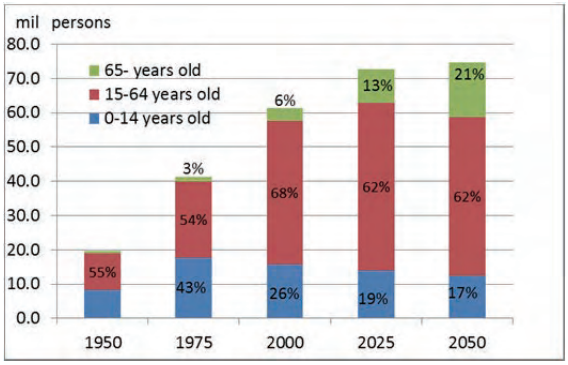
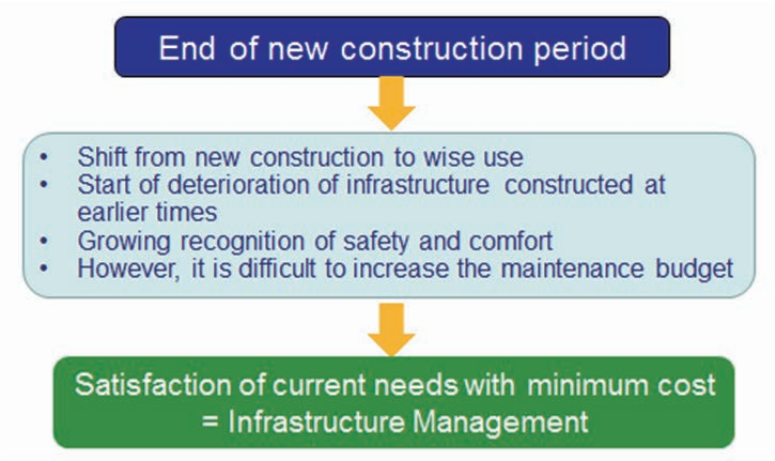


Figure 43 Demographic Statistics of Thailand (1950 – 2050)

Source: UN Demographic Yearbook

The developed countries, long past the infrastructure construction phase, are encountering problems arising from deterioration of infrastructure facilities constructed in earlier times and

are therefore becoming more aware of the importance of securing comfort and safety. With only limited funding for maintenance, the budget cannot be increased. Therefore, the developed countries are now in the phase of maintenance and replacement of the existing infrastructure facilities to ensure long useful life of them. The concept of infrastructure management is becoming valued as a system to achieve this goal with small expenditure.



There are signs that Thailand will also trace the same path. Unlike other countries, however, the demand for construction will continue even after the start of a phase of maintenance and replacement of infrastructure facilities. To maintain the competitiveness against the ASEAN countries, Thailand will need to implement both of them at the same time, therefore it has to devise ways to further improve the efficiency of constructing and maintaining infrastructure facilities.

4.2 Current Status of the National Government

4.2.1 Roles of National Government

Four of the national government organizations that are the target of this study, the National Economic and Social Development Board (NESDB), Bureau of the Budget (BOB), Public Debt Management Office (PDMO), and State Enterprise Policy Office (SEPO), conduct national-level policy formulation, planning and management of budgets and debts, and management policy formulation and performance evaluation of state enterprises. The roles of organizations influential to maintenance are outlined in the table below.

Table 30 Roles of National Government Organizations

Target organizations	Roles Influential to Maintenance
NESDB	● To formulate a national plan and determine project policy and priority areas ● To create a project evaluation guidebook for F/S to be conducted by an implementing organization for proposal of a new project
BOB	● To formulate an annual budget plan and allocate and manage budget
PDMO	● To formulate the debt plan of the nation ● To manage public debts ● To arrange for debt financing for projects determined to be implemented
SEPO	● To formulate policies and evaluate performances of state enterprises ● To evaluate and advise on self-financing as a stockholder of 56 state enterprises ● To examine the investment types of state enterprises

(1) Types of Target Organizations

Out of the organizations that are the target of this study, there are 12 implementing organizations in charge of maintenance of facilities as listed below. They consist of three government agencies, eight state enterprises, and one municipality. The competent authorities for them are shown in Table 26.

Table 31 Institutional Status of the Target Organizations and Infrastructure Maintained

Supervising Line Ministries	Institutional Status	Target Organizations	Infrastructure Maintained
Ministry of Transport	Government Agency	DOH	National roads
		DRR	Rural roads
	State Owned Enterprise	EXAT	Toll express ways
		SRT	National Railway
		MRTA	Subway
Ministry of Interior	Government Agency	DPT	Village roads
	State Owned Enterprise	MWA	Waterworks in the metropolitan area
		PWA	Waterworks outside the metropolitan area
		MEA	Power transmission grid in the metropolitan area
		PEA	Power transmission grid outside the metropolitan area
Ministry of Energy	State Owned Enterprise	EGAT	Power generation facilities and distribution grid
Ministry of Natural Resources and Environment	State Owned Enterprise	WMA	Sewerage outside of Bangkok
–	Municipality	BMA	Municipality roads and sewerage in Bangkok

Whereas the above national government organizations formulate plans directly, government agencies and state enterprises are engaged in budget review. Applications for new projects described in the subsequent sections concern the government agencies and state enterprises. Municipalities, under great influence from national plans, review and determine budgets themselves.

(2) Application for New Projects

Large projects to be implemented by government agencies and state enterprises must be approved by the Cabinet in advance. The definitions of a large project vary depending on the regulations of an implementing organization. For example, there are varying definitions such as “a project of 50 million baht or more” or “a change of 5 million baht or more in self-financing or debt.” New projects include large-scale repair and replacement projects[54], for which the application scheme is shown in Figure 37. Unlike applications for annual budgets, this application can be submitted anytime and undergo an assessment because the application timing is not determined. The actual project implementation phase is conducted as follows: When an annual budget is applied for, the budget for the projects to be implemented in that year are included in the budget plan of the implementing organization.

[54] In the planning and budget review phase, new projects refer to newly implemented ones, not necessarily newly started ones. Most of the projects other than daily inspection or maintenance are included in new projects.

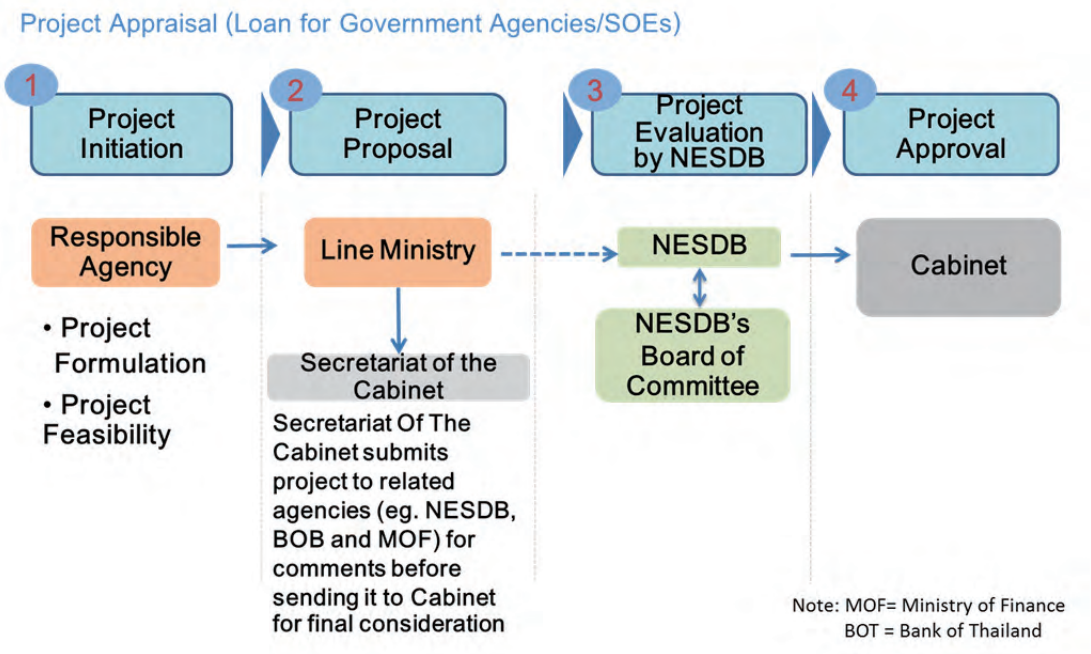


Figure 44 Project Application and Review Scheme

Source: NESDB

(i) The implementing organization conducts F/S, formulates a project plan including fund-raising, and submits it to the competent authority.

(ii) The competent authority reviews the project plan, submits it to NESDB and, via the Cabinet, to relevant agencies such as BOB and PDMO. The relevant agencies review the project plan from their respective points of view such as the budget plan and debt plan and prepare to be able to give advice as necessary at Cabinet meetings.

(iii) NESBD reviews the project plan to ensure that it is consistent with the policies of the national plan. At the same time, it coordinates activities of the relevant agencies such as BOB and PDMO.

(iv) The Cabinet discusses the project plan and determines the implementation of the project.

(3) Application for Annual Budget

The government agencies and state enterprises in Thailand must formulate a budget plan every year and obtain approval from the National Assembly. The state enterprises are basically on a self-financing basis. Even the state enterprises that run their enterprise using their own income submit a budget plan for reference and explain it at the National Assembly in the same way as for other organizations.

For many of the organizations in Thailand, the fiscal year starts from October. Fiscal Year 2014 lasts from October 2013 to September 2014. Therefore, a budget plan for the next fiscal year

starts to be prepared by the year-end and gets approved by the National Assembly at the end of September the next year. The scheme is shown in Figure 38.

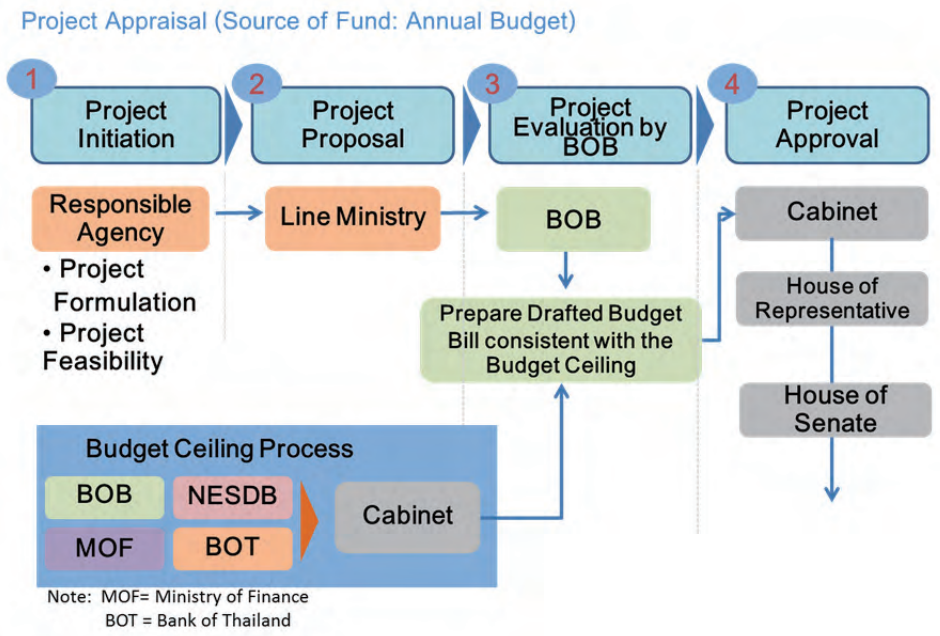


Figure 45 Application for Annual Budget and Review Scheme

Source: NESDB

(i) The line agency prepares an annual budget plan, consistent with the Annual Budget Allocation Strategy and Ministerial Strategic Plan, and submits its budget request to the corresponding ministry.

(ii) The line ministry reviews agency's budget request for policy consistency and then submits it to BOB.

(iii) BOB prepares the drafted budget bill and submits to the cabinet for approval. NESDB and MOF inform the Cabinet of their opinion on the budget bill from their respective points of view.

(iv) The cabinet submits the budget bill to the legislative branch for approval.

The roles of each organization are described in the following sections.

4.2.2 National Economic and Social Development Board (NESDB)

NESDB works out a "National Economic and Social Development Plan", which is a national 5-year plan. This plan is fundamental for the nation, based on which the budget is allocated to each organization. All the projects by national government organizations shall be

implemented in accordance with this plan. Since the issue of the 8th plan, human-centered development is the backbone of the plan instead of economic growth and this is also the case of the currently effective 11th plan (2012-2016). In the 11th plan a commitment was made to strengthen infrastructure management as a strategy for sustainable development aiming at the reinforcement of the Thai economy and social capital and the improvement of risk management towards and the realization of a happy society. The 12th plan currently under formulation retains the same infrastructure-related policies as in the 11th plan, which focus on the improvement of railway networks to enhance the competitiveness against the surrounding countries.

The infrastructure-related roles of NESDB include the approval of master plans developed by ministries and state enterprises and the preparation of guidelines to be used in feasibility studies of new development projects in regard to such areas of environmental and social assessment, economic and financial analysis and investment planning. The statuses of sectors are recognized as follows:

- For the road sector, maintenance will be emphasized as more priority is placed on railways.
- For the railway sector, priority will be placed on new investment to enhance the railway network.
- The waterworks sector has no problem in MWA and PWA coverage areas with good conditions. However, PWA has large water supply areas with regional differences so that an adequate level of service has not reached remote, sparsely populated areas.
- The sewerage sector has a problem of not being able to charge for the services.
- The power sector has a good financial state and is free of maintenance problems.

NESDB also elaborates other policies in anticipation of nation's future by investigating infrastructure needs and priorities in a looming aging society. It considers that infrastructure maintenance can be more efficient and cost effective due to technical improvements and that dismantling of existing infrastructure will be the last resort.

Moreover, it has been involved in the introduction of public-private partnerships (PPP) as a new means of funding. The secretary-general of NESDB is a review committee member together with the Ministry of Finance and other implementing organizations. However, a means of securing a funding source for maintenance is yet to be found because no fare receipts can be expected for maintenance.

4.2.3 Bureau of the Budget, Office of Prime Minister

The Bureau of the Budget (BOB) advises the government on the budget allocation to each agency based on the National Economic and Social Development Plan (NESDP), the Annual

Budget Allocation Strategy, and other national priorities. In the 2014 budget, 102,789.9 million baht out of the total budget of 2,525,000 million baht is allocated to the infrastructure development. With the main objective to augment the national competitiveness, the plan includes the development of ports and airports, the enhancement of railway networks and the construction, maintenance and upgrading of local roads and bridges.

Figure 44 shows that a new project is reviewed by one of the 11 departments in charge of respective sectors. First, a committee in charge of each sector reviews a project in terms of the capacity of the implementing organization, Value for Money, and past performances.

Regarding budget allocation on road projects, in the past, national priority was more or less focused on road construction. However, in recent years activities related to maintenance have become increasingly important at the national policy level. For maintenance, there is some debate in BOB over whether priority should be placed on construction or maintenance. However, the current prime minister announced a policy to place priority on maintenance and therefore priority will be placed on maintenance in the future. For the road sector, an eight-year strategic traffic infrastructure plan was recently formulated, placing priority on four points: (i) Connectivity, (ii) Border line, (iii) Missing links, and (iv) Bottlenecks.

4.2.4 Public Debt Management Office (PDMO), Ministry of Finance

PDMO manages all the public debts, formulates debt management plans for state enterprises and ministries, and validates the debts in the process of budget application. Validation takes account of economic internal rate of return (EIRR) from the viewpoint of public benefit as well as repayment capability and financial internal rate of return (FIRR). When the project plan is approved, PDMO looks for lending agencies for the implementing organizations and negotiates about the debt conditions to determine them. A debt management plan for each fiscal year is prepared and submitted by each government agency or state enterprise together with a budget bill. PDMO collectively reviews and incorporates them into an annual plan from the viewpoints of necessity, repayment capability, and impact on the economy.

As a result of changes of government policy, domestic loan sources are preferred in recent years to eliminate money exchange risks and to keep transaction costs low. This policy change is expected to stimulate the domestic financial market. External loans are still utilized when it is cost effective or when the revenue obtained in the future is in foreign currency.

4.2.5 State Enterprise Policy Office (SEPO), Ministry of Finance

SEPO formulates management policies of 56 state enterprises in various industries as a stockholder of them. Every year, SEPO prepares and issues a Statement of Directions (SOD), policies to be observed by a state enterprise in a project plan in collaboration with NESDB and the Office of the Prime Minister. The SOD declares long-term policies for five years and short-term policies for one year for each of the sectors and state enterprises. Each state enterprise formulates a five-year plan with one-year investment plans according to these policies.

The following shows the 2012 SOD for each state enterprise. For the water supply sector, asset management is incorporated in the policies to maximize the effects.

Overall policy
Mechanism for economic and social strategies of the country on efficiency implementation on "Good Governance"

Road sector
Develop infrastructure and logistic system to create network and service to be standard and support mass transportation service including development of logistic system to increase competitiveness of the country and promote private participation.
EXAT Develop expressway to support development of logistic system and urban development including creating value-added from asset to get financial return in suitable level and has a debt management plan concretely. **SRT** Develop administration management system, quality of service and develop infrastructure on rail system to be main transportation system with efficiency and reduce burden of government sector. **MRTA** Implement mass rail transport project linking as network covering whole Bangkok and its vicinity including can have revenue to its organization to reduce burden of government sector.

Waterworks and sewerage sector
Fulfill basic needs and support to upgrade people's quality life including asset management for the maximum benefit.
MWA Develop and expand water supply network to be qualified and enough for urban expansion including develop relevant business to add value to organization. **PWA** Develop and expand water supply network in rural area to be sufficient and effective including finding and develop raw water source sufficiently and capital management effectively. **WMA** Find and manage wastewater treatment system effectively for social acceptance.

Power sector
Create stability in term of power sector of the country, support and develop clean alternative energy for supporting effective utilization of energy and effective capital management including social and environmental supervision.
EGAT Create confidence on sufficient, stability and quality of electricity system of the country: Develop electricity production from alternative energy with consideration of impact to social and environment including capital management and resources of organization effectively. **MEA** Develop electric distribution system to be quality and sufficient to needs of the country, create business partner, develop relating business in order to create value-added from asset and have responsibility to social and environment. **PEA** Develop electric distribution system to be quality and sufficient to needs of the country, create business partner, develop relating business in order to create value-added from asset and have responsibility to social and environment.

Furthermore, SEPO is divided into sections in charge of respective sectors, each of which reviews the strategy planning and business performance of the state enterprises to manage them and provides advice on their management policies and uses of retained earnings. Business performance review includes the examination as to whether financial capacity is sufficient for infrastructure investment.

The sector-specific policies are as follows: Regarding EXAT in the road sector, repayment of debts before due dates is proposed because the financial status is improving and a new investment scheme is being studied for the new and extension road segments currently under feasibility study because stable revenue can be expected from expressways.

MWA in the waterworks and sewerage sector, having sufficient retained earnings, is advised to invest in replacement of old piping to decrease the water leakage rate to 20% or less within five years and 10% or less within ten years. However, it is reluctant to make investment in replacement because it requires debts that need funding costs. Furthermore, government debts will be supplied to PWA to allow it to construct new pipelines in areas with inferior profitability so that the water supply coverage will be 100% within ten years.

SEPO will supply two types of assistance to state enterprises: Investment for construction and a subsidy called PSO. In 2010, Public Service Obligation (PSO) was launched, whereby a subsidy is provided to state-owned companies in order to compensate their deficit when they cannot set economically viable service fees. PSO is granted if all of the required conditions are met, such as when the government has the right to pricing. To apply for the subsidy of PSO, a state enterprise must hand in its financial statements and an application form which describes public services concerned, target groups of the service, the amount of subsidy and payment schedule and the appraisal result of the validity of PSO more than 10 months before

the beginning of fiscal year.[55] At the time of writing this report, the state enterprises that PSO is applied are SRT and Bangkok Mass Transit Authority (public bus operator), which have been suffering a serious downturn in business.[56]

On the other hand, each government corporation pays to SEPO part of net profit, which is said to be a dividend in case of private companies. The proportion of the dividend to net profit has a range of 35 – 45% subject to the yearly negotiation with SEPO and is fixed as far as there are no sudden changes of financial conditions or unpredictable events. It is set at 45% for all the target organizations. The exception is SRT, which has not produced profit and no dividend has been paid. After payment to SEPO, the dividend becomes the income of national treasury.

SEPO is examining various investment schemes such as PPP and will try new investment schemes starting from EXAT and other such agencies that are expected to have a stable revenue and be attractive to investors. In fact, the routes constructed by EXAT in 1990 and later are outsourced to private companies in BTO contracts. New schemes will be examined and applied to new routes to be constructed in the future. SEPO intends to improve the financial performance of the state enterprises and eventually increase external investment from the infrastructure funds, etc. However, the involvement of the government will not be decreased because the government's ratio of stock holding has been determined in each of the laws for the state enterprises.

[55] From the Website of SEPO.
[56] Interview with SEPO.

4.2.6 Department of Public Works and Town & Country Planning (DPT), Ministry of Interior

The Department of Public Works, responsible for public works, and the Department of Town & Country Planning, responsible for city planning, were merged to form the present DPT in 2002, however, their organizational structure and responsibilities have not changed.

The Department of Public Works provides assistance to construction and maintenance of infrastructure facilities of villages which are mainly dikes to protect villages from floods and village roads, water supplies and power facilities necessary for the operation of these infrastructure facilities.

Since 2012, in line with a government policy of decentralization, the responsibility of infrastructure development in villages was transferred from the central government to local authorities, and the local authorities without enough financial or technical capacity were to be supported by DPT. DPT first plans and constructs the infrastructure facilities and then is responsible for maintenance until the operation and maintenance is transferred to the local authorities 2 years later. In these two years, villages are in charge of daily inspection and they ask DPT for appropriate repairs and reinforcement of facilities which they find to have issues needing work. The regional offices of DPT implement ordinary maintenance such as removal/pruning of vegetation, painting, minor repairs and reinforcement that cost ten million baht or less whereas the DPT headquarters implement repairs and reinforcement that cost more than ten million baht. When the local authorities cannot afford maintenance costs, DPT provides budget even after the transfer. On the other hand, the local authorities which have adequate funds conduct planning and construction by themselves without any direct involvement of DPT.

As a result of the additional operation, the DPT's budget has increased rapidly from 2012 and so has the maintenance cost. From 2014, the budget sharply increased due to the addition of large-scale repair implemented by the DPT headquarters. However, it has a smaller ratio of maintenance cost than the facility owner agencies because, in principle, it provides maintenance assistance to municipalities that ask for assistance within two years of a facility's construction.

Table 32 Trend of DPT's Budget and its Budget for Maintenance

Unit: Mill baht

Cost item	Project size	Organization	2011	2012	2013	2014	2015
DPT Maintenance & repair cost (1)			9.5	60.0	60.0	324.6	324.5
Inspection and general maintenance		Provincial Office	9.5	9.5	9.0	7.0	16.9
Repair and renovation cost	< 10 mil baht		-	50.5	51.0	35.8	85.1
Repair and renovation cost	>= 10 mil baht	Headquarters	-	-	-	281.9	222.5
DPT Total Budget (2)			6,559.7	11,295.6	15,792.0	19,329.7	23,210.6
% of maintenance cost (1) / (2)			0.14%	0.53%	0.38%	1.68%	1.40%

Source: DPT

The maintenance section of DPT has 15 machines and staff of about 30 officers and 20 workers. The daily inspection is carried out by the local authorities and when there are any problems DPT's officers and workers go to the scene and take necessary measures. When budget is requested by a local authority, DPT's officers carry out field observation, review the content of documents submitted and include necessary cost in its budget application. DPT also provides technical guidance on maintenance and repair to villages with little experience of maintenance. However, it only provides assistance for maintenance and repair of infrastructure facilities and does not own or manage any assets.

Meanwhile, the Department of Town & Country Planning is responsible for long-term urban planning nationwide. Anticipating the shift to an aging society and intending to develop disaster-resistant and environmentally-friendly cities, it is proposing a plan with a focus on infrastructure facilities that meet future social needs and are easily maintained. However, some of such proposals do not fit with the NESDB's policy that considers international competitiveness, as exemplified by the determination of an airport construction site with emphasis on access to Bangkok, and are not yet matured enough to be integrated into a national plan.

4.3 Current Status of the Bangkok Metropolitan Administration (BMA)

4.3.1 Infrastructure Management System of BMA

BMA is responsible for the maintenance of municipality roads and the sewerage system in Bangkok area. In BMA, Public Works Department, Traffic and Transportation Department is in charge of bridges, traffic lights and other affiliated facilities and Drainage & Sewage Department sewage. The detailed maintenance works of road and sewerage by BMA are described in the sections on the road sector and the water and sewerage sector, respectively.

(1) Financial Status of BMA and its Budget for Maintenance

BMA prioritizes the following 6 issues in its budget allocation. The right cells show the projects planned in the budget for the year 2015. From this listing, it is found that infrastructure development is considered to be important and fundamental for safety, happy lives and the improvement of quality of life.

Table 33 Priority Issues in BMA's Budget for the Year 2015

Focus Issues	Main Projects
Investment for safety	Introduction of devises for safety control and purchase of CCTV
Investment for happiness	Improvement of convenience through efficient public transportation Improvement of access to medical facilities by new facility construction
Investment for greenery and sanitation	Solid waste management and the enhancement of wastewater treatment facilities
Investment for learning	Promotion of cultural activities of younger generation
Investment to provide opportunities to everyone	Improvement of convenience for the aged and the disabled
Investment for ASEAN	Improvement of economic value through tourism

Source: BMA

The following table shows BMA's revenue and its expenditure according to the service categories. BMA must allocate budget within its revenue as it is not allowed to take on loans. Roads and sewerage are important sectors since they account for 25-30% of the total budget and their budget amount and appropriation have been increasing.

Table 34 BMA's Budget of Recent Years (2012-2014)[57]

Unit: Mill baht

Item	2013		2014 Budget	
Regular Revenue	63,111	100%	65,000	100%
Local Taxes collected by BMA	11,306	18%	10,743	17%
Taxes from the central government	48,661	77%	51,200	81%
Income from fee, fines miscellaneous activities	3,143	5%	3,057	5%
Special Revenue				
Accumulate	9,900	13%		0%
Total revenue	76,153	100%	68,057	100%
Budget Appropriation by Bangkok Development Plan				
General Administration	14,624	24%	17,119	29%
Public Cleaning and Orderliness	11,765	20%	12,634	21%
Civil Works and Traffic System	9,908	17%	11,520	19%
Water Drainage and Sewage Management	5,309	9%	5,724	10%
Social Development and Servies	7,122	12%	6,864	11%
Public Health	5,170	9%	5,522	9%
Education	6,102	10%	5,616	9%
Total Expenditure	60,000	100%	65,000	100%
Net profit	16,153	21%	3,057	4%

Source: BMA Annual Report

Table 35 Budget Appropriation to Departments (2013-2014)

Unit: Mill baht

Item	2013		2014	
Traffic and Transportation Department	3,103	7%	3,103	7%
Public Works Department	3,214	8%	3,309	7%
Drainage & Sewage Department	4,422	10%	4,958	11%
Total appropriation for departments	42,461	100%	46,366	77%

Source: BMA Annual Report

Table 36 Breakdown of Budget for Repair and Maintenance

Unit: Baht

	2013		2014	
Traffic and Transportation Department	106,954,000	3.4%	115,735,000	3.7%
	39,975,000		42,735,000	
	66,979,000		73,000,000	
Public Works Department	263,000,000	8.2%	300,000,000	9.1%
	100,000,000		100,000,000	
	163,000,000		200,000,000	
Drainage & Sewage Department	125,753,000	2.8%	118,584,300	2.4%
	2,800,000		2,800,000	
	17,770,000		17,770,000	
	17,772,000		17,772,000	
	1,000,000		1,000,000	
	20,000,000		20,000,000	
	50,000,000		50,000,000	
	808,000		808,000	
	8,403,000		2,557,500	
	7,200,000		5,876,800	
Total Budget for maintenance and repair	865,661,000	1.4%	950,054,300	1.5%

Note: Figures in percentage is the proportion to the total budget appropriation to the concerned departments.

Source: BMA

[57] Special Revenue is the accumulation of unused budget in the past.

Maintenance budget for the road sector has been growing in terms of both amount and proportion. Public Works Department spends nearly 10% of its budget on maintenance.

(2) Budget Application and Approval Scheme of BMA

BMA's budget is managed internally by the Department of Budget. A budget application schedule is determined in November or December every year and announced to each department together with maximum budget amount. Each department submits its budget request to Department of Budget around in January and the request must be attached with study results about the public interest of each project. Department of Budget has a staff of 156 persons, and 120 among them in charge of budget deliberation are divided into groups, each of which reviews reports from a specific department and evaluates the public interest and social influences of each budget application. In case of 2015, the amount of budget requested by all the departments reached 115 billion baht, far beyond the budget of 65 billion baht.[58] Department of Budget submits the budget bill to the metropolitan assembly within 90 days prior to the commencement of the next fiscal year, which is October 1st. The metropolitan assembly must finish its deliberation for approval within 45 days. As for the projects which extend more than two fiscal years, 10% of cost is allocated in the first year, and the budget allocation from the next year will be determined depending on project progress. Unused budget can be carried over only to the next year.

[58] BMA.

4.4 Road Sector

4.4.1 General Information of Road Sector

(1) Classification of Roads

The total length of roads in Thailand is approximately 400,000 km, and Department of Highways (DOH) in Ministry of Transport (MOT) is responsible for approximately 51,000 km, Department of Rural Roads (DRR) in MOT is responsible for approximately 50,000 km and local governments are responsible for approximately 300,000 km and Expressway Authority of Thailand in MOT is responsible for 207 km.

Table 37 List of Road Categories

Category	Responsible	Description
National road (Highway)	DOH	Main roads connecting main cities in the whole country. It is divided into the following three groups. 1st grade: Roads connecting provinces. The road numbering used are 1 or 2 digit numbers. 2nd grade: Roads connecting cities within the province. The road numbering used are 3 digit numbers. 3rd grade: Road connecting district capitals. The road numbering used are 4 digit numbers
Local road	DRR, Internal Security Operations Command, Royal irrigation department	All roads – that don't fit into the other categories listed, – outside of municipal jurisdictions. Are constructed by a number of organizations depending on the intended purpose. DRR is responsible for construction and maintenance of roads in rural areas, and in addition DRR is responsible for some roads within Bangkok and bridges crossing Chao Phraya River.
Municipal road	Municipality, Local governments	Road network within cities managed by local governments. In Bangkok, BMA is responsible for both construction and maintenance of roads, and DRR constructs roads in other municipalities.
Intercity highway	DOH	High standard toll road known as "motorways".
Urban highway	EXAT	High standard toll roads in Bangkok metropolitan area and its vicinity operated by EXAT; called "expressways".

Source: Economic status of Thailand in 2008/2009

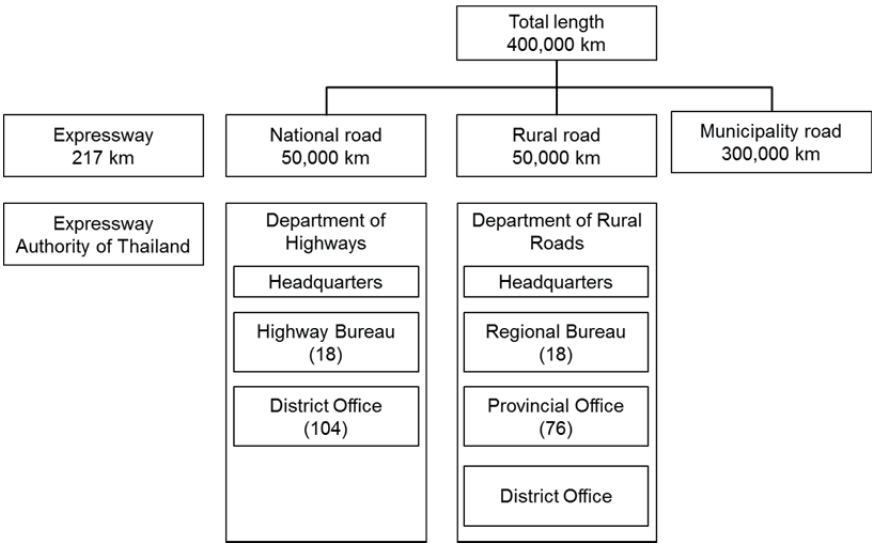


Figure 46 Roads in Thailand

Source: JICA Data Collection Survey on Road and Bridge Maintenance, 2013

(2) Budget for Roads in MOT

The budgets for roads in MOT are summarized in the table below.

Table 38 Budget for Road Departments in MOT

Unit: Baht

Department	2012	2013	2014
MOT	119,975.7	131,504.1	132,682.0
DOH	50,422.1	52,966.3	53,179.2
DRR	29,597.1	33,951.4	36,202.1
EXAT	4,488.8	4,152.8	2,802.5
OTP	464.1	639.6	706.9
Others	35,003.6	39,794.1	39,791.3

Source: MOT

(3) Regulations and Manuals

There are many existing regulations and manuals for construction, supervision, maintenance for roads and bridges in Thailand. They were mainly based on the American Association of State Highway and Transportation Officials (AASHTO) or American Concrete Institute (ACI) building codes.

In Japan, for example, although there is a maintenance manual for bridges prepared by Ministry of Land, Infrastructure, Transport and Tourism (MLIT), local governments use their own maintenance manual which suits their local conditions, because it is too difficult for them to use

the same maintenance manual as MLIT uses due to their limited capacity in terms of human and budget resources. As for Thailand, the regulation and manuals produced by a particular department are shared within that department, however they are not shared with organizations outside of the department.

Table 39 Regulation and Manuals for Roads and Bridges

Name	Date of issue	Own by
Inspection Manual for Expressways	1990.3	EXAT
Manual for Inspection of the Rama IX Bridge	1990.3	EXAT
Specifications for Highway Construction	2003	DOH
Bridge Strengthening Manual	2006.5	DOH
Bridge Inspection, Analysis and Evaluation Manual	2006.5	DOH
Bridge Repair and Maintenance Manual	2006.5	DOH
Work Instruction for Bridge and Box Culvert Construction	2006	DOH
Procedure for Construction Management of RC Bridges and Condition Evaluation including Maintenance Method	2000.8	DRR
Manual for Construction and Maintenance of Road	2003	DRR
Project for Development of Management System for DRR's Road Network (Phase 1)-Manual for Bridge Inspection and Evaluation-	2007.2	DRR
Bridge Inspection and Improvement Manual	2007.9	DRR
The Industrial Ring Road Project – Inspection and Maintenance Manual -	2008.1	DRR
Study Project for Repair Method for Damages due to Material Deterioration and Service Life of Bridges in DRR's Road Network (Phase 2) - Final Report -	2009.9	DRR
Project for Maintenance and Management System Development for DRR's Bridges - Manual for repair of RC bridge components due to deterioration of bridge structures and components	2009.12	DRR
Inspection and evaluation manual	2011.3	DRR
Formulation manual for long term maintenance plan for bridges	2011.3	DRR
Routine Maintenance Manual	2011.6	DRR
Inspection and evaluation manual	2013.7	DRR
Formulation manual for long term maintenance plan for bridges	2013.7	DRR
Manual for flooding and restoration	2013.7	DRR

4.4.2 Department of Highways (DOH)

(1) General Information

1) Roads

DOH is a major road organization in Thailand which is responsible for planning, construction and maintenance of the roads connecting main cities. The total length of roads controlled by DOH is 51,413 km as of 2013, equivalent to 68,254 km as 2 lanes roads, and 66,811 km is open for traffic. As for bridges, DOH controls 14,939 as of 2014.

Table 40 DOH Road Length by Surface Type

Unit: km

Region	Actual distance	Distance per 2 lanes			
		Concrete	Asphalt	Unpaved	Total
North	15,703	795	17,476	265	18,536
North Eastern	15,092	942	18,033	13	18,988
Central	10,754	3,141	14,164	8	17,313
South	9,864	425	12,922	68	13,415
Total	51,413	5,303	62,595	354	68,252

Source: DOH Annual Report 2013

Table 41 Section Length by Road Type

หน่วยงาน (Bureau)	ระยะทางจริง (กม.) Distance (Km.)	ชนิดผิวทางต่อ 2 ช่องจราจร (Surface Type Per 2 Lanes)														
		Cold Mix	Micro Seal	Slurry Seal	Cape Seal	DST.	SST.	P.M.	Un Std.PM.	SA	other	Conc.	AC.	Mod AC.	รวมผิวลาดยาง Total Asphalt	รวมระยะทางต่อ 2 ช่องจราจร (กม.) Total Distance Per 2 Lanes
สำนักทางหลวงที่ 1(เชียงใหม่)	3,959.451	0.000	31.374	349.212	981.002	163.573	12.536	0.000	0.000	155.460	0.100	529.363	2,492.387	0.000	4,030.184	4,715.007
สำนักทางหลวงที่ 2 (แพร่)	3,763.637	5.900	0.000	113.189	148.969	701.548	84.982	0.000	0.000	51.960	0.000	18.335	3,123.550	0.000	4,178.138	4,248.433
สำนักทางหลวงที่ 3 (ลพบุรี)	2,918.750	0.000	0.000	0.891	186.825	102.104	24.857	0.000	0.000	0.000	4.336	112.258	3,154.331	0.000	3,453.344	3,565.602
สำนักทางหลวงที่ 4 (พิษณุโลก)	3,295.811	2.913	0.000	33.220	406.031	88.199	7.638	0.000	0.325	3.064	0.000	193.838	3,248.363	0.000	3,766.689	3,963.591
สำนักทางหลวงที่ 5 (ขอนแก่น)	2,846.831	0.000	0.000	31.727	302.790	57.097	107.319	0.000	0.000	0.000	1.041	370.758	2,746.952	0.000	3,246.926	3,617.684
สำนักทางหลวงที่ 6 (เพชรบูรณ์)	2,859.874	0.000	0.000	0.000	552.082	57.891	1.700	0.000	0.000	0.000	0.000	3.473	2,710.826	0.400	3,322.899	3,326.372
สำนักทางหลวงที่ 7 (อุบลราชธานี)	3,454.849	0.000	0.000	6.926	319.963	194.811	26.572	0.000	0.000	0.000	0.000	9.461	3,549.072	0.000	4,097.344	4,106.805
สำนักทางหลวงที่ 8 (นครราชสีมา)	3,722.412	0.000	0.000	0.000	316.952	8.274	0.000	0.000	0.000	7.845	0.000	447.596	4,250.754	82.804	4,658.784	5,114.225
สำนักทางหลวงที่ 9 (สหบุรี)	2,959.803	0.000	0.000	78.646	165.834	47.117	5.952	0.000	0.000	1.415	43.275	311.973	3,681.113	0.000	4,021.937	4,335.325
สำนักทางหลวงที่ 10 (สุพรรณบุรี)	3,315.231	0.000	0.000	169.849	99.830	17.881	0.000	0.000	0.000	0.800	0.000	800.252	3,408.327	0.000	3,685.887	4,486.939
สำนักทางหลวงที่ 11 (กรุงเทพ)	1,853.580	0.000	0.000	0.000	12.196	0.271	40.556	0.000	0.000	6.080	0.000	1,685.430	2,308.196	440.384	2,801.603	4,493.093
สำนักทางหลวงที่ 12 (ชลบุรี)	2,625.096	0.000	0.000	51.404	229.245	27.270	33.029	0.000	0.000	0.000	0.000	343.372	3,314.055	0.000	3,655.003	3,998.375
สำนักทางหลวงที่ 13 (ประจวบคีรีขันธ์)	2,221.588	0.000	0.000	12.485	110.544	195.151	0.000	0.000	0.000	0.000	0.000	234.813	2,835.701	88.912	3,242.793	3,477.606
สำนักทางหลวงที่ 14 (นครศรีธรรมราช)	3,142.378	4.028	0.000	31.696	255.181	354.329	1.280	0.000	0.000	23.758	8.749	155.001	3,282.736	0.000	3,937.999	4,116.758
สำนักทางหลวงที่ 15 (สงขลา)	2,825.509	0.000	0.000	3.140	207.010	92.421	15.150	0.000	0.000	0.000	0.000	33.408	3,463.178	0.000	3,780.899	3,814.307
สำนักงานทางหลวงกระบี่(สุราษฎร์ธานี)	1,674.190	22.112	0.000	0.000	91.696	110.922	0.000	2.171	0.000	44.597	0.000	2.200	1,733.661	0.000	1,980.562	2,007.359
สำนักงานทางหลวงตาก	1,824.252	0.000	0.000	92.690	278.162	66.921	17.162	0.000	0.000	54.575	9.110	50.076	1,713.901	0.000	2,177.946	2,282.597
สำนักงานทางหลวงปราจีนบุรี	2,149.348	0.000	0.000	93.343	56.125	36.659	20.883	0.000	0.000	5.150	0.000	1.734	2,370.006	0.000	2,577.016	2,583.900
รวม	51,412.890	34.953	31.374	1,058.418	4,700.437	2,302.439	399.616	2.171	0.325	354.684	66.611	5,303.341	53,387.109	612.500	62,595.953	68,253.978

Source: DOH Annual Report 2013

2) Organization

There are 18 highway bureaus under the headquarters of DOH, and 104 district offices under the highway bureaus. There are one or two district offices in each province. There are 3,574 staff in the headquarters, and 634 are technical staff and 2,940 are general staff. As for the whole DOH, there are 6,405 officers, 5,506 permanent staff, and 3,090 government staff.

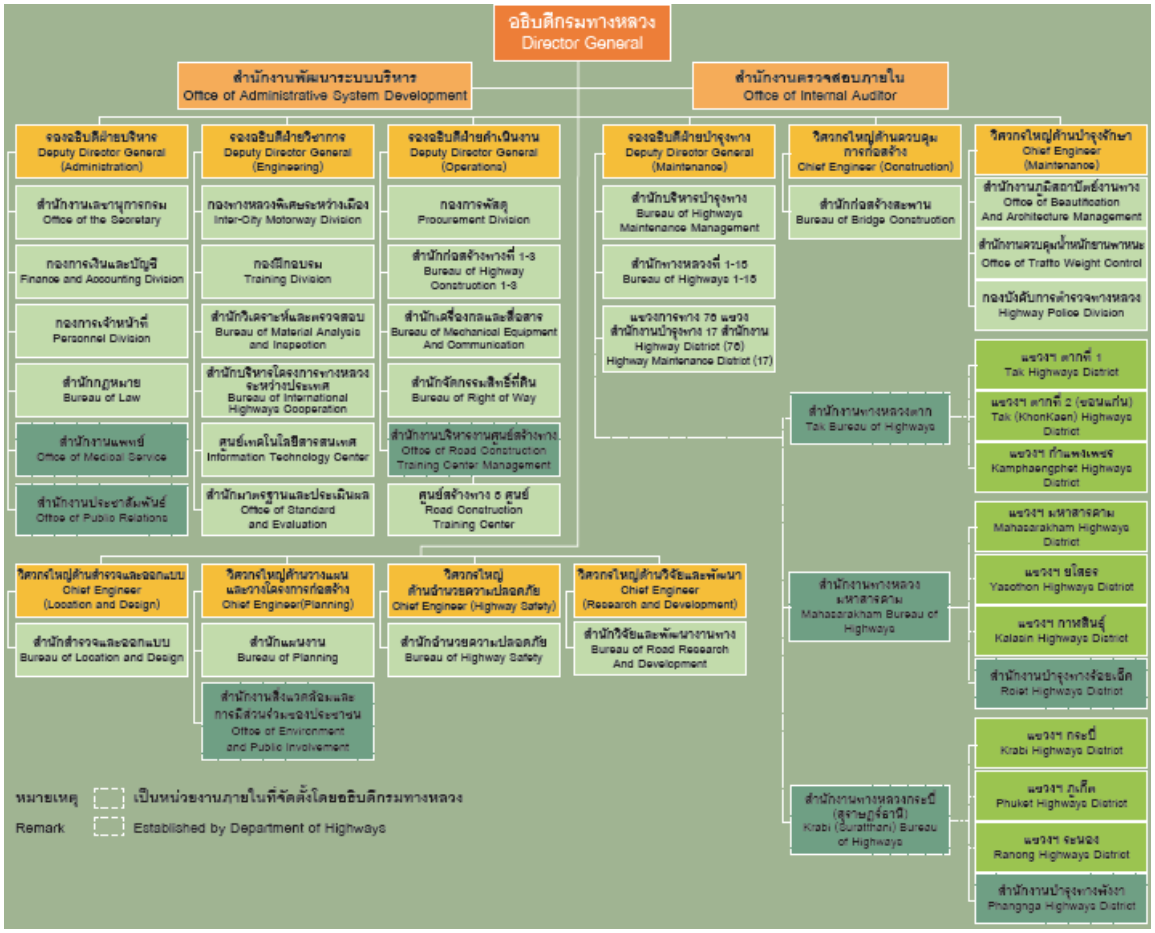


Figure 47 Organization Chart of DOH

Source: DOH Annual Report 2013

3) Financial Conditions

The DOH budget in FY2015 is 61,378 million baht, of which 38,775 million baht (64%) is for maintenance and repair costs. The trend of DOH budget shows that budget for new construction peaked during 1990's and is now decreasing, while budget for maintenance and repairs is gradually increasing and in 2011 exceeded the budget for new construction, although this is partly due to the damage caused by flooding.

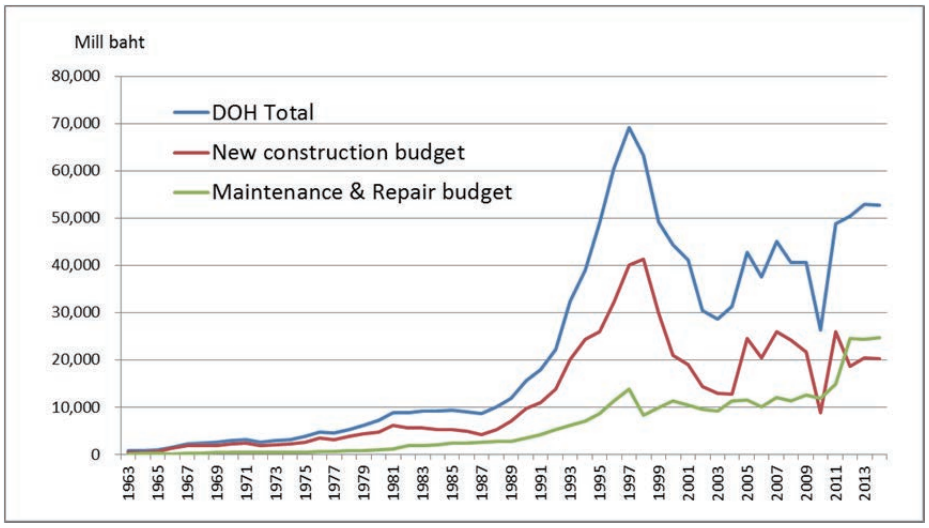


Figure 48 Trend of DOH Budget for New Construction and Maintenance & Repair

Source: DOH

The maintenance division of DOH uses the work code for budget management. The general maintenance is classified as Routine, Periodic, and Special Maintenance. Budget for the Routine maintenance is nearly constant at 3,960 million baht, whereas budget for the Periodic and Special maintenance is increasing these days.

Table 42 Breakdown of Maintenance Budget

Unit: Mill baht

Code	Maintenance work	2012	2013	% in 2013
1	Road maintenance	19,527	17,302	81%
1.1	Highway maintenance	9,660	12,464	59%
1.1.1	Rountine maintenance	3,960	3,964	19%
1.1.2	Periodic maintenance	2,200	3,000	14%
1.1.3	Special maintenance and rehabilitation	3,500	5,500	26%
1.2	Restoration of highways affected by disasters	9,492	4,108	19%
1.3	Disaster remedy and restoration	200	200	1%
1.4	Landscape and highway architecture improvement	45	100	0%
1.5	Administratice and supporting activities	130	430	2%
2	Rehabilitation of Major Highways	4,000	4,000	19%
	Total	23,527	21,302	100%

Source: DOH Annual Report

(2) Pavement

1) Plan

DOH has set the indicators for road maintenance in their Strategic Issues as "The percentage of roadways with International Roughness Index (IRI) less than 3.5." This is understood as the DOH's primary policy for the road maintenance.

The Bureau of Highways formulates a three-yearly rolling plan mainly as a communication tool, and requests the budget yearly.

The maintenance budget is classified as shown below.

Table 43 Code No. of the Maintenance Budget

Code No	Name of budget
1000	Routine Maintenance Work
1100	Surface Maintenance Work
1200	Wayside maintenance work and footpath and bicycle lane
1300	Drainage System Work, Bridge and Structure
1400	Traffic work and safety facilities
1500	Wayside Work and highway rest-house
1600	Maintenance Machine Service Work
2000	Periodic Maintenance Work
2100	Asphalt pavement work
2200	Asphalt surface pavement work
2300	Non-asphalt pavement work
2400	Changing material on connecting surface concrete work
3000	Special Maintenance Work
3100	Surface road leveling work
3200	Asphalt pavement repairing work
3300	Asphalt pavement improvement work
3400	Reuse existing concrete
3500	Concrete Surface Repairing Work
3600	Wayside repairing work
3700	Bridge Repairing Work and Structure
4000	Rehabilitation Work
4100	Asphalt pavement rehabilitation work
4200	Concrete pavement rehabilitation work
5000	Improvement Work
6000	Solving and Prevention Work
7000	Safety Work
8000	Emergency Work

The maintenance budget is classified in accordance with the concept shown in the following figure.

The maintenance budget for pavement is divided into three categories such as routine maintenance, periodic maintenance and special maintenance. Routine maintenance is the works executed every day to maintain the road condition, and periodic maintenance is executed periodically while it is in fair condition as a preventive measure, and special maintenance and rehabilitation are executed after the road condition has deteriorated.

The work executed after the condition is seriously deteriorated is classified in Reconstruction budget and dealt with as new construction. As for the difference between Rehabilitation and Reconstruction, Rehabilitation is the work excluding sub-base reconstruction and Reconstruction is the work including sub-base reconstruction.

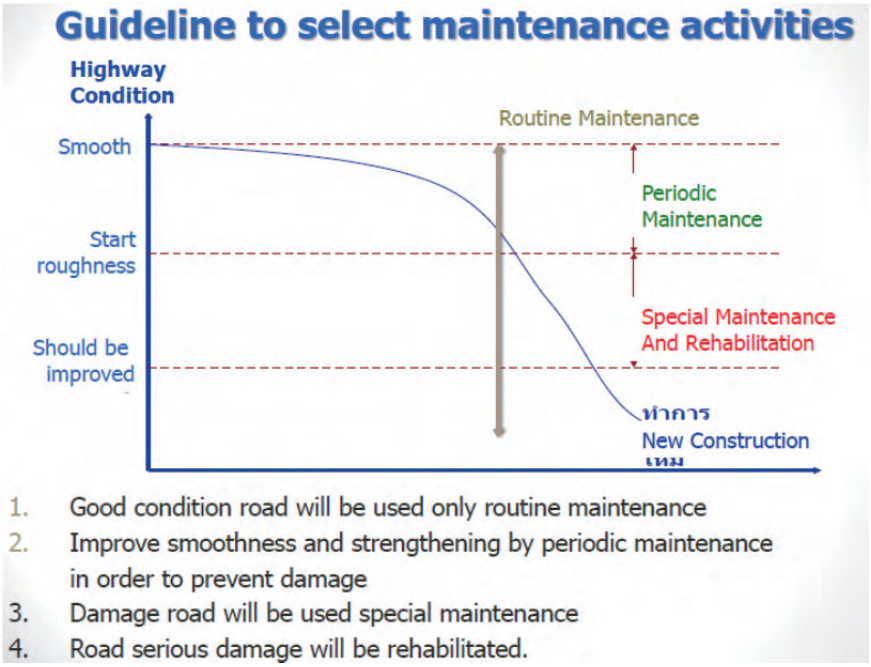


Figure 49 Classification Guideline for the Maintenance Budge

Source: DOH

The routine maintenance budget for each district office is determined by a function of road length, number of lanes, age of pavement, traffic volume and number of lighting poles and other road asset quantity by each classification of the road surface condition. There are eight classifications of the road surface condition. The periodic maintenance budget and the special maintenance budget are used for periodical road repairing and rehabilitation, and each project is designed and estimated by the district office by using road surface condition survey data provided by the headquarters.

The budget proposal and approval stream within DOH is shown in Figure 50. In this figure, Corrective maintenance budget includes Special maintenance and Rehabilitation budgets.

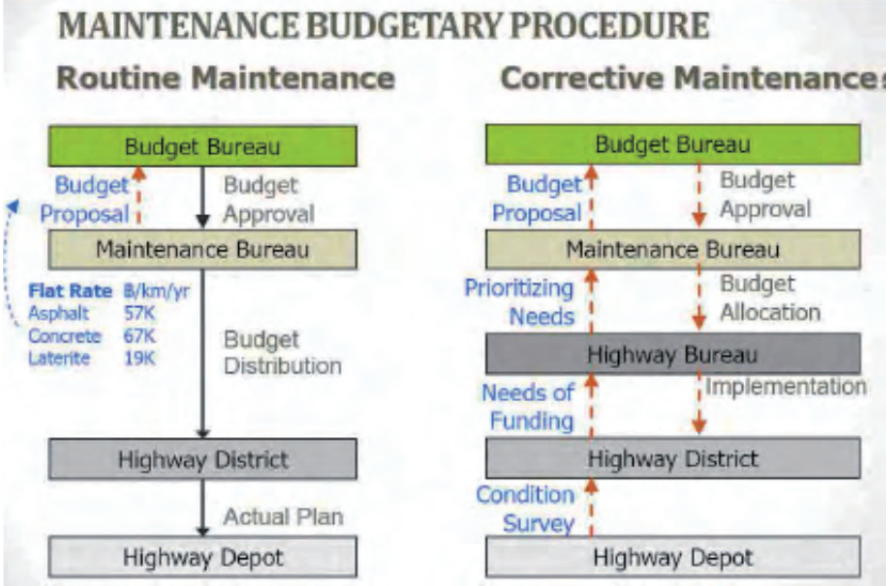


Figure 50 Budget Proposal and Approval Stream within DOH

Source: DOH

The routine maintenance budget includes salaries, utility costs, material costs and outsourcing costs. The routine maintenance works are conducted either directly or by contractors, while all periodic and special maintenance works are conducted by contractors. District offices are able to contract out the work amounting to less than 10 million baht and the bureau of highways is able to contact out the work amounting to less than 15 million baht.

Bureau of Planning is responsible for the preparation of DOH's entire budget.

DOH uses Thai Pavement Management System (TPMS) which assists to prepare the strategy for the medium and long term maintenance system and to prepare the optimum maintenance plan within the available budget.

DOH has been using TPMS since 1984 in order to decide the pavement maintenance method to meet the road surface condition and to prioritize the road sections to be repaired for the formulation of the road maintenance plan. In 1989, TPMS was revised by combining with HDM-3 produced by the World Bank so that it can be used as a tool to formulate a maintenance plan. This was used until 2008. In 2009, Chulalongkorn University developed the Central Road Database (CRD) and upgraded TPMS to TPMS2009 under contract.

TPMS2009 was developed based on the simulation model of HDM-4 with the function of pavement deterioration prediction, the improvement by maintenance work, social cost and environmental impacts. This model equipped with the optimization computer model developed by Chulalongkorn University which can be used for the strategy analysis for the formulation of five-year pavement maintenance plans and for the estimation of budgets. TPMS2009 uses the data collected from data in CRD as input data for analysis. At present, the output by TPMS2009 is dealt with as reference in DOH.

2) Implementation (Do)

Road maintenance technical department is responsible for the formulation of road maintenance plans, budget control and technical training, while the road maintenance department with 18 bureaus and 104 district office is responsible for operations.

Figure 51 Inspection and Evaluation Sheet

Headquarters

a. Road Surface Condition Survey

There are two kinds of inspection for pavement in DOH, one is the road surface condition survey conducted using road surface survey vehicles under the headquarters' supervision, and the other is visual inspection conducted by district offices. As for traffic volume survey, the headquarters supervise the automatic traffic volume monitoring stations and the district offices do manual traffic surveys at the specific points.

The national road network survey for road surface conditions is conducted by three universities, Chulalongkorn, Tamasaart and Kasetsart, on a contract basis. Kasetsart University sub-contracted out their work to STS company. DOH has a plan to conduct this survey every two years.

Hawk Eyes produced by ARRB is used as a road surface survey vehicle. Chulalongkorn, Tamasaart, STS company and Bureau of Materials and Analysis and Inspection both poses a Hawk Eyes. The cost of Hawk Eyes is approximately 20 million baht and the survey unit cost is approximately 800 baht per km. It can capture the data of IRI, rutting, cracking and raveling, and the data can be analyzed either automatically or manually. Although Hawk Eyes is able to capture data even when travelling at 100 km per hour, the actual operation is conducted at 60 to 70 km per hour and the productivity is about 150 km per day. The Hawk Eyes owned by DOH is used inspect whether a new road or a rehabilitated road meets the contracted standards at the time of hand over. In addition, the Hawk Eyes of DOH is used for the survey of the road surface in order to collect data for the estimation of special maintenance.

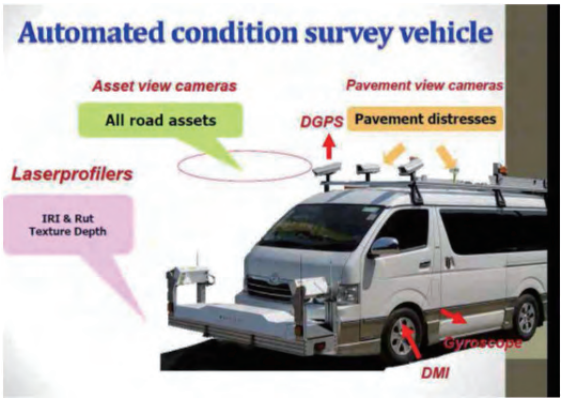


Figure 52 Hawk Eyes Produced by ARRP Company

Source: DOH

Bureau of highways maintenance management conducted the 1st road surface condition survey in 2007 for inputting the measured data into TPMS and periodically conducted the same to accumulate the data.

Table 44 History of Road Surface Condition Survey

2007	1st round asphalt pavement survey of 60,000 km
2008	CRD
2009	TPMS online plan
2010	2nd (2.a) round asphalt pavement survey of 45,000 km.
2011	2nd (2.b) round asphalt pavement survey. 1st concrete pavement survey. A road surface survey vehicle was procured.
2012 to 2013	3rd round asphalt pavement survey of 23,000 km. Start CRD system. Start online plan. Route account improvement. Disaster management and emergency situation.

b. Overweight Truck Control

One of main causes of highway damage is the passage of overweight trucks. In order to solve this problem, DOH, by the Highway Weight Control Office operates 69 weigh stations in 2013. In addition, DOH established 2 Virtual Weigh Station in 2013 by installing devices for weighing on the highways. When an overweight truck runs through the device, the device will record photo and weight data, which will be sent through a Wifi network to the authorities to proceed with legal action.

For the year 2013, the weight of 30,744,665 trucks was inspected. There were 1,393 overweight trucks which is 0.004 % or considered as 4.5 overweight trucks for every 100,000 trucks. When compared to the same data in 2004, the overweight truck ratio is 122 for every 100,000 trucks. It can be seen from the data that the number of overweight trucks are declining dramatically which demonstrates the effectiveness of the weigh station.

Table 45 Inspection Data of Overweight Trucks

Fiscal year	Number of weight station	Number of weighed vehicles	Number of overweight vehicles	Percentage of overweight vehicles	Overweight vehicle per 100,000 vehicles
2009	59	18,989,177	1,566	0.008	8.2
2010	64	21,670,726	1,150	0.005	5.3
2011	67	26,758,599	1,647	0.006	6.2
2012	69	25,045,686	1,351	0.005	5.4
2013	69	30,744,665	1,393	0.004	4.5

c. Technologies to Extend Life

The condition of life extension technologies which DOH has introduced is described.

- To use the polymer modified asphalt of which durability was improved by adding rubber or epoxy resin as modifier is getting popular in Thailand and this technology can be carried out by the local contractor successfully. Composite pavement having the asphalt pavement on top of the concrete slab has both benefits of the durability of concrete pavement and

running comfort and ease of maintenance of asphalt paving. Test construction of composite pavement has been executed in Bangkok, however it is assessed as improper technology because cracks in pavement occurred in a short period due to weak ground. Difficulty of obtaining appropriate aggregate for composite pavement near Bangkok and the expensive cost are other issues to be overcome for the adoption.

- SMA (Stone Mastic Pavement) pavement of which durability was improved by increasing the coarse aggregate ratio has been constructed for some sections such as near intersections which require high durability and it has been highly assessed.

d. Training of maintenance

Maintenance system development section carries out the maintenance training for DOH staff every year and teaches the importance of preventive maintenance, utilization of PMS, deterioration curve of road pavement, concept of LCC, etc. comprehensively in order to raise staff's awareness and to improve their knowledge of maintenance.

District Office

District offices are in charge of survey of road condition, estimation of budget, execution of budget, daily inspection of road condition and collection of data for evaluation.

In order to supplement the road surface survey data conducted by the headquarters, district offices collect additional data such as photos taken at site, visual inspection data, etc. District offices also use IRI data measured by road surface condition data given by the headquarters to do the preliminary design of pavement maintenance work. It is sometimes too difficult for district offices to do visual inspection according to the existing road inspection manual due to the heavy traffic condition. In order to cope with this problem, generally they divide a road into several segments and they rate the road condition of each segment and sum up the total length of road by category of road surface evaluation.

According to the existing manual for implementation of maintenance work, district offices submit the budget request with the priority list of the projects to the headquarters. The headquarters prepares the annual implementation programme taking the priority list and other projects such as flood protection plan, tourism plan, etc. into account. Then, district offices execute the repair works according to the approved programme. District offices do not have the right to reallocate the budget for repair.

As for traffic volume survey, the headquarters supervises the automatic traffic volume monitoring stations and the district offices do manual traffic surveys at specific points.

The district office staffs daily carry out visual inspections of roads and take pictures at sites. For example, Samutsakhon Highway District, there are eight road routes in this district and 490 km as two lanes (most segments are more than six lanes) in total. There are four inspection

teams that carry out daily inspections and maintenance of roads. Each team consists of one leader, two technical staff and 20 to 30 workers. All inspection and maintenance data is input into the database. The data is utilized for daily maintenance work and also for analyzing the productivity of the maintenance work. The manual for visual inspection of road surface conditions is utilized.

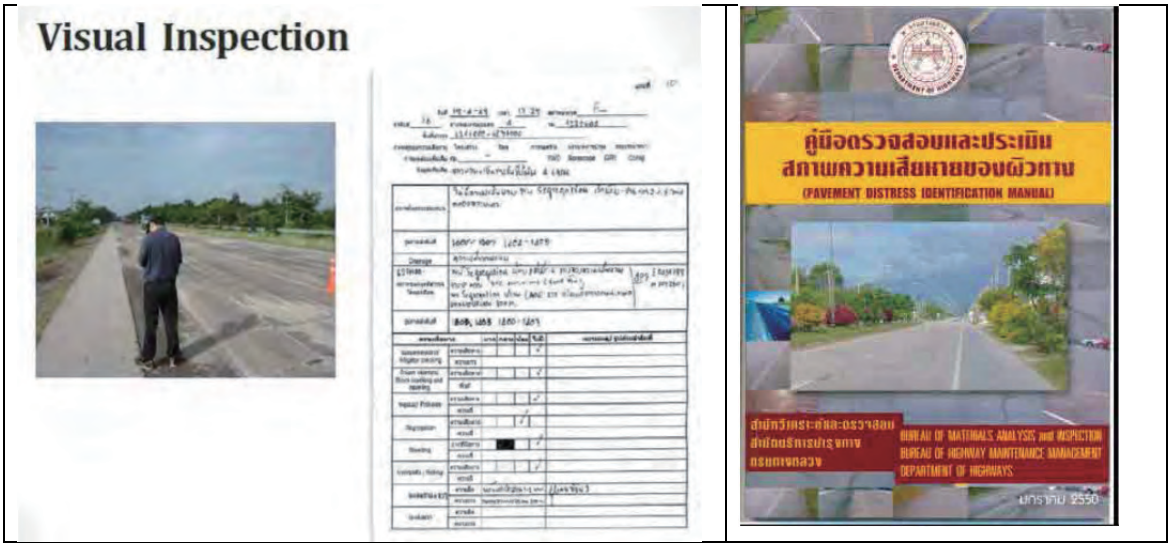


Figure 53 Maintenance Manual and Inspection Sheet

Source: DOH

3) Evaluation (Check)

The result of road surface condition survey conducted in 2012 is shown in the figure. The average of IRI in the whole country was 2.85 m/km, and IRI in every region satisfied the required IRI, 3.5 m/km.

Table 46 Result of Road Surface Condition Survey

(measure between Dec. 2011 and Apr. 2012)

Results of IRI Survey for Asphalt Pavement Highway

(December 2011-April 2012)

Part	Bureau of Highways	Survey Distance (Km.)	Average IRI (m/Km.)
Northern Part	1	2,709.37	3.36
	2	2,604.96	3.08
	4	2,522.60	3.16
	6	2,537.30	2.73
	Tak	1,846.38	3.45
	Total	12,220.61	3.14
North-East Part	3	2,699.47	2.57
	5	2,670.31	2.88
	7	2,801.76	2.90
	8	3,235.75	2.57
	Mahasarakham	1,935.31	2.51
	Total	13,342.60	2.69
Central Part	9	2,903.04	3.09
	10	2,425.73	2.70
	11	1,752.41	2.85
	12	3,399.34	2.91
	Total	10,480.52	2.90
Southern Part	13	2,584.11	2.61
	14	3,368.98	2.49
	15	1,884.80	3.11
	Krabi	2,287.17	2.62
	Total	10,125.06	2.66
	Whole Country	46,178.79	2.85

Source: DOH annual report 2013

Various data such as road surface condition survey data, traffic volume data, the budget for periodic maintenance and special maintenance submitted by district offices are all input to CRD and the data can be utilized for various purposes.

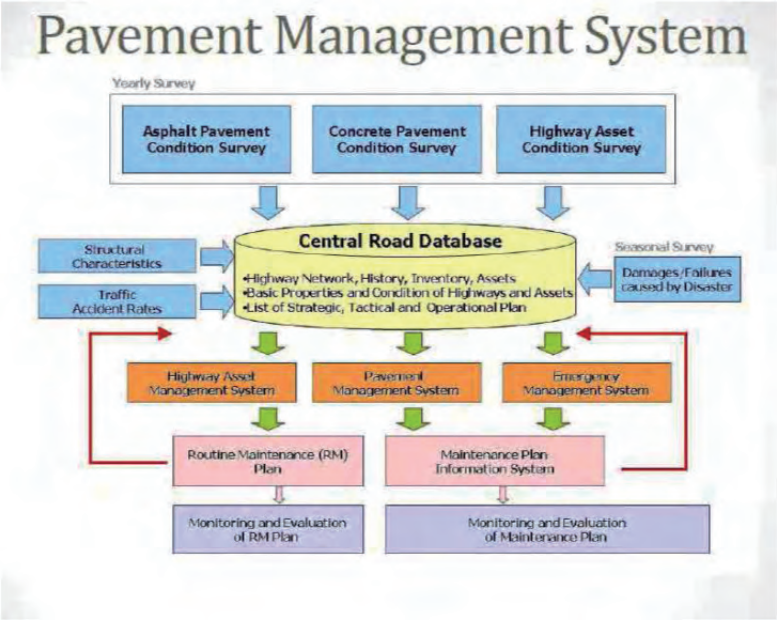


Figure 54 Structure of Road Maintenance Management System

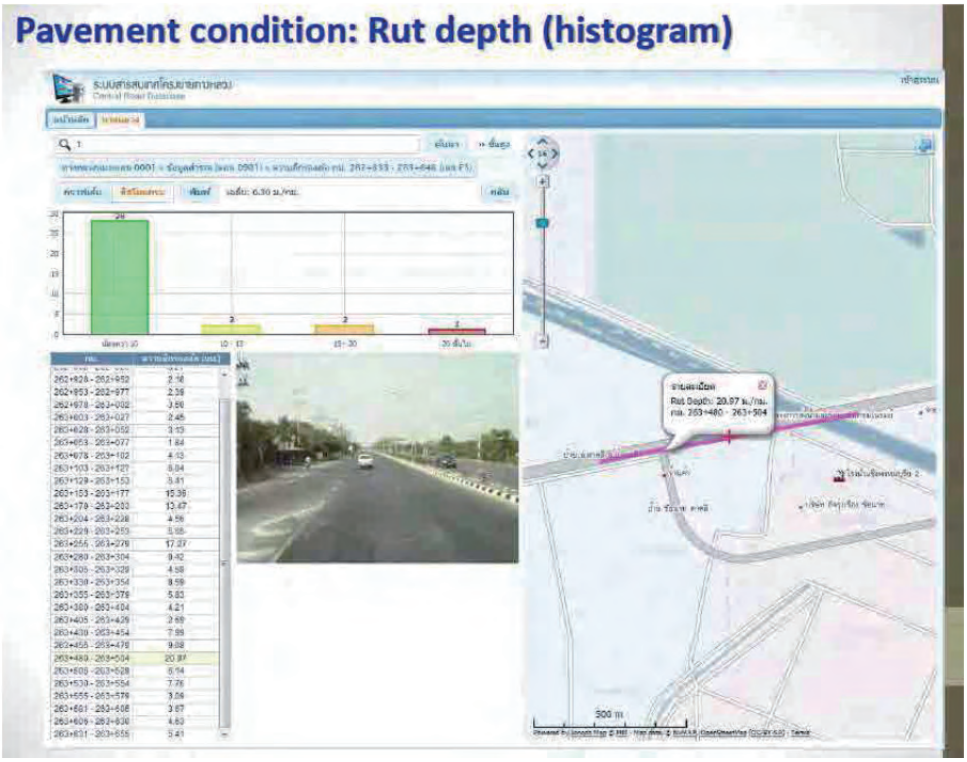


Figure 55 Screen Shot of Road Maintenance and Management System

Source: DOH

DOH uses the following systems for roads.

1. Central Road Database (CRD)
2. Roadnet
3. Highway Asset IT Program
4. Routine maintenance management program
5. Thailand Pavement Management System (TPMS)
6. Estimated Cost Plan IT Program (Online Plan)
7. Disaster Management Program, Emergency Situations and Traffic during Festivals.

4) Review (Action)

The role of present utilization of TPMS is regarded as reference and guideline for planning and budgeting. In order to fully utilize TPMS for various purposes such as evaluation of the plan and reviewing the plan for the improvement of the data stock and data analysis and utilization capacity is weighted.

(3) Bridges

1) General condition

Bridge construction has been actively carried out since the 1980s in Thailand, and it has continued up to the present. In the Bangkok metropolitan area, since the passage of heavy vehicles is restricted, the influence of overloaded vehicles, which can often be a major cause of damage to bridges, is low, and therefore the state of the existing bridges is relatively good. As shown in the figure, among the bridges managed by DOH, about one-third of the total number of bridges are more than 30 years old. However, priority is still on the construction of new roads and bridges. This may be due to the fact that no serious accidents such as collapsed bridges have occurred, and therefore the social interest in bridge maintenance management is still low.

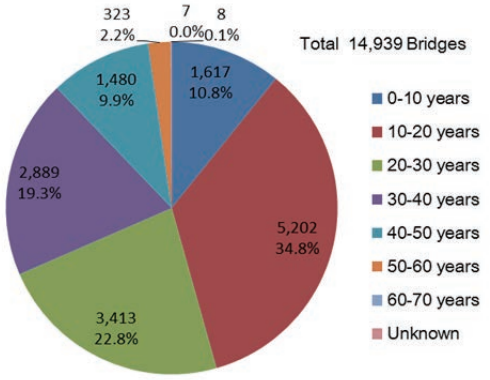


Figure 56 Number of Bridges by Age Category as of Feb. 2014

Source: DOH

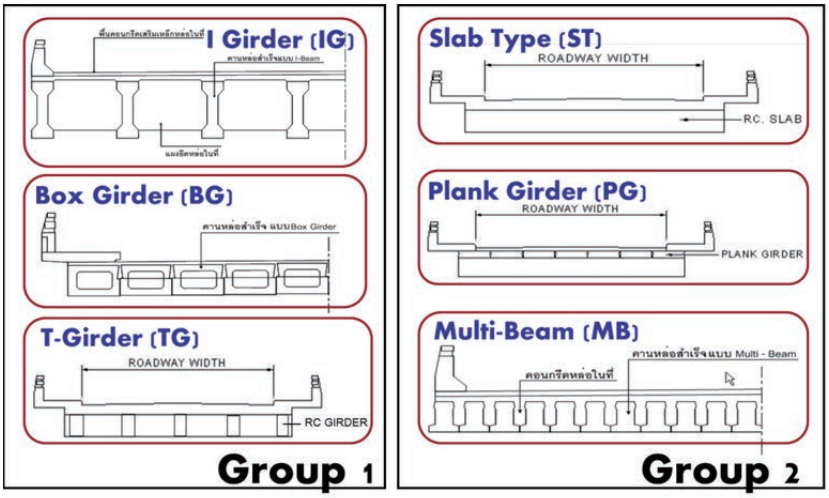


Figure 57 Classification of Bridges used by DOH

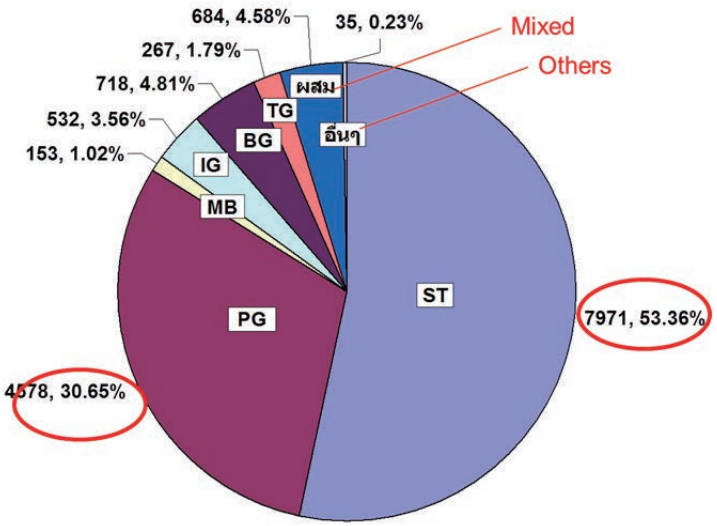


Figure 58 Number of Bridges by Type

2) Plan

Inspection, analysis and evaluation of bridges are carried out according to Bridge Inspection, Analysis and Evaluation Manual created in 2006, and the maintenance of the bridge is carried out according to the Bridge Repair and Maintenance Manual created in 2006.

As for bridges of 10m or more in length, a unit of ten staff from the Bureau of Bridge Construction, in DOH headquarters, is in charge of special inspections and maintenance of bridges, the repair of the bridge deck pavement and so on. On the other hand, district offices are responsible for maintenance and inspection of bridges of less than 10m in length.

3) Implementation (Do)

There are three kinds of inspection system used for bridges.

Routine Inspection

Local officials implement the routine inspection of all bridges every two years. As the method of inspection, bridge photos are taken from three different directions and stored in the Bridge Maintenance and Management System (BMMS). If there is any damage found, the observation record is input into the BMMS.

Principle Inspection

Under the Bureau of Bridge Construction, there are four bridge construction and rehabilitation centers in the country. They carry out the principle inspection for the bridges every 4 to 6 years. The inspection method is to save in the BMMS observation records and photos of piers, superstructures, members of wall railings, etc., as well as more detailed photos of damaged parts.

Special Inspection

After a disaster such as a flood occurs, staffs of Bureau of Bridge Construction directly implement the inspection of damaged bridges.

As for cracks, only significant cracks are measured using a dedicated ruler called a crack scale. Although the inspection manual exists, the implementation of inspections are highly based on the experience of the technician, therefore the inspection data highly depends on the inspector's competence.

At present the inspection results have not been maintained in electronic format, therefore comparisons with the other bridges and continued observation of deterioration or damage is difficult, and deterioration prediction analysis and damage trends have not yet been possible.

4) Evaluation (Check)

Bureau of Research and Development of DOH started to develop the new database, but the Bureau of Bridge Construction of DOH contracted out to develop a BMMS (Bridge Maintenance and Management System) to Kasetsart University in 2011 and it was completed in August 2012.

The web-based BMMS has as its foundation a geographic information system (GIS), and its purpose is to analyze the soundness of bridges and to plan the optimum repair period and cost estimation using stored data such as bridge type, materials used, construction year, traffic volume and the importance of the road.

Recently, the Bureau of Bridge Construction started to use 25 tablets known as "iBRIDGE" which can access the BMMS. The input items to BMMS are bridge number, bridge name, purpose of bridge (river bridge, overpass, etc.), location, route name, width, and superstructure type, etc. and also photographic data and drawing data can be stored.

The BMMS consists of seven modules, 1) Inventory, 2) Inspection, 3) Evaluation/Analysis, 4) Prioritization / Budgeting, 5) Output / Report, 6) Data Administration, 7) Help Menu.

- Data of Bridge database developed by Bureau of Research and Development in 2008 is used as Inventory data
- Bureau of Bridge Construction developed the bridge inspection manual and also gave training to DOH staffs.

- In evaluation and analysis, there are three kinds of evaluation system ready. One is selection of optimum repair method and cost estimation to meet the damage conditions, and another is estimation of remaining life span, and another is estimation of load bearing ability. DOH evaluates the remaining life span of common types of bridges such as slab type and box girder type by using a convenient method. DOH is also researching the evaluation method for viaducts and cable-stayed bridges.
- Prioritization and budgeting are judged by the score calculated by five elements, 1) degree of damage, 2) average daily traffic volume, 3) road class (1 to 4 digits), 4) the impact of delays caused by the measures to be implemented, and 5) the current bridge value. The budget is allocated in the highest priority to about 20 bridges for which closures should be avoided due to its historic value, high economic value and/or its international relations value.

Originally, the BMMS was supposed to be utilized for developing a maintenance budget plans over the medium to long term, and also for prioritizing bridges to be repaired and calculating maintenance costs. However, collection of data for 14,939 bridges managed by DOH has not been completed.

For about 5,000 bridges, updates of bridge photos and bridge basic information have been inputted into the BMMS, however as for data input of the remaining 10,000 bridges has not been completed. In order to fully utilize the BMMS's capacity, there is a need to continue to improve the staff's inspection skills, improve their analytical techniques for judging the condition of bridges, to improve their ability to predict bridge deterioration, and to improve organizational capacity.

5) Review (Action)

Budget requests are prepared and submitted every year. The headquarters judges the priority of the bridges to be repaired by referring to the bridge inspection data sent by district offices and prepares the next year's budget. Prioritization is conducted on the basis of the site photos, and there is room for improvement for cost calculation and quantity applied to the repair. In order to improve these issues, BMMS's capacity should be fully utilized for budget planning for bridges. Therefore, there is a need to continue to improve the staff's inspection skills, improve their analytical techniques for judging the condition of bridges, to improve their ability to predict bridge deterioration, and to improve organizational capacity.

(4) Maintenance budget

The workflow of bridge maintenance budget approval is shown in Figure 59. The approval workflow for ordinary inspection and maintenance and for inspection and maintenance for emergencies are different.

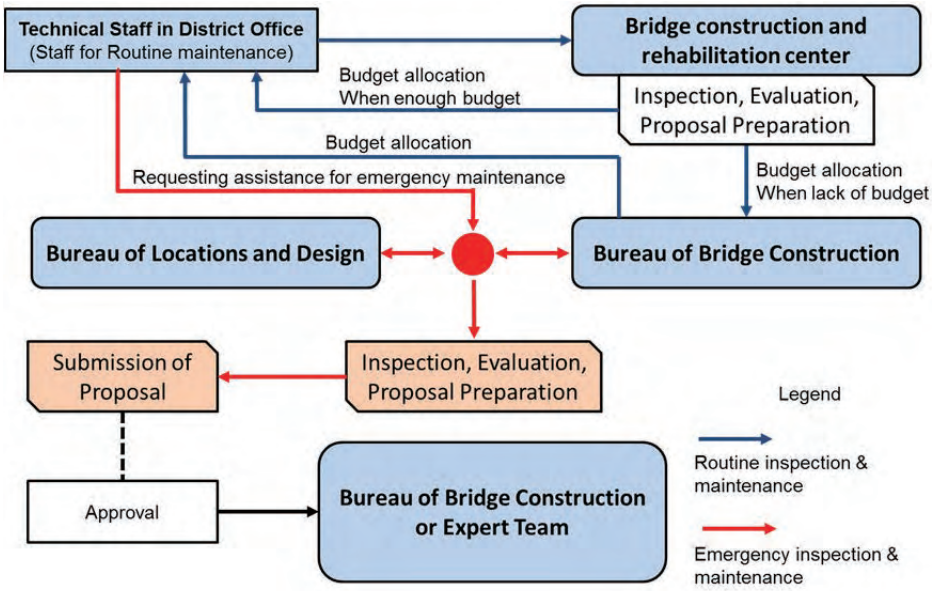


Figure 59 Workflow of Budget Approval for Bridges

Source : Project Formulation Survey on popularization of 3D maintenance method for structures by Japan's high-tech survey instruments and measurement technologies

(5) Assessment of Present Condition of Asset Management and Issues

In the field of asset management, in terms of engineering and economics, which are the cornerstone of infrastructure management, DOH is currently working very hard to strengthen inspections and to strengthen its database. In addition, DOH is actively doing the research and development of life extension technologies and executes training of maintenance to staff every year to give knowledge and skills. The gradual increase of preventive maintenance budget is for the sake of these continuous efforts.

The practical sections in DOH have been making considerable efforts to improve the asset management condition by understanding its importance and it is, therefore, considered to be useful to establish the higher level plan which promotes the adoption of life extension measures in infrastructure management.

4.4.3 Department of Rural Roads (DRR)

(1) General Information

1) General information of facility

DRR is responsible for construction and maintenance of roads connecting cities in rural areas. The total length of roads managed by DRR is approximately 40,000 km and the number of structures managed by DRR is approximately 8,000, including 4,100 bridges and 3,900 box culverts. As for bridges, DRR manages not only bridges in rural areas but also the main bridges crossing the Chao Phraya River in Bangkok metropolitan area.

2) Organization

DRR consists of 18 regional bureaus and 76 provincial offices, and DRR has established 81 district offices under provincial offices in line with the establishment plan for 376 district offices in total so that they can reach all sites for daily inspection and routine maintenance within two hours.

DRR has a director general position, three deputy director general positions and one chief engineer position, and as for in the headquarters, there are 12 bureaus and one centre and three offices.

There are 1,600 permanent employees and 1,800 temporary employees in regional bureaus and provincial offices and the number of employees is planned to be increased with the increase of district offices.

DRR's work covers construction of main roads in rural areas, maintenance of roads, preparation of standard drawings and technical specifications, and preparation of manuals for inspection and maintenance, etc. In addition, DRR conducts technical training for staff in local authorities by implementing a training seminar at provincial offices and dispatching lecturers for training to local governments.

The Bureau of Bridge Construction and the Bureau of Road Maintenance are in charge of the maintenance of brides crossing the Chao Phraya River in Bangkok metropolitan area, and 18 bureaus of rural roads are in charge of the maintenance of all other bridges.

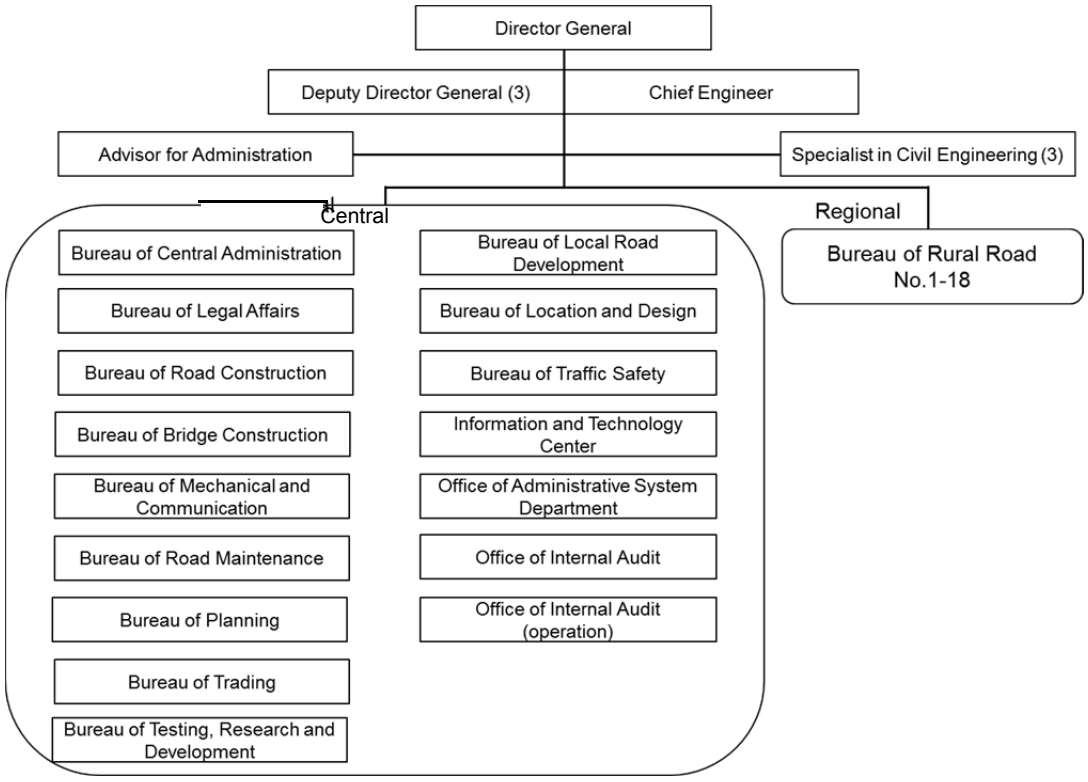


Figure 60 Organization Chart of DRR

Source: ODA Project Formulation Survey on popularization of 3D maintenance methods for structures using Japan's high-tech survey instruments and measurement technologies, March 2014, joint venture between Kansai Construction Survey and Oriental Consultants

3) Financial conditions

The DRR budget for FY2012 was 29,597 million baht, where the budget for maintenance for roads and bridges in 2012 was 13.5 billion baht and this was about 20% of the budget amount requested by DRR.

- Routine maintenance for 47,436km : 2,555 mill baht
- Periodical maintenance for 830 km : 2,135 mill baht
- Special maintenance for 410 km: 1,722 mill baht
- Emergency maintenance: 80 mill baht
- Survey and inspection : 126 mill baht

The DRR budget is increasing 33,951 million baht in FY2013 and 38,045 million baht in FY2014. In FY2015 it is 40,597 million baht, where the budget for maintenance and repair is 21,256 million baht (53%), the maintenance and repair budget is also increasing.

(2) Pavement

1) Plan

The headquarters prepares the three years mid-term plan and the annual plan. Provincial offices prepare not only three-year mid-term plans and annual plans but also yearly, quarterly, and monthly action plans.

DRR introduced a PMS called the PMMS (Pavement Maintenance Management System) in 2005. This system is different from the TPMS used by DOH because PMMS has to suit more variety of roads managed by DRR.

PMMS is a web-based system and consists of seven modules.

1. Road Inventory Module
2. Road Condition Database
3. Treatment Strategy Analysis Module
4. Budget and Cost Database
5. Prioritization Analysis Module
6. Maintenance History Database
7. Presentation and Reporting Module

Currently inspection data is being compiled into the PMMS and research is underway into how to analyze the data for deterioration projection and lifecycle cost analysis.

As for the present workflow of the preparation of budget, provincial offices in charge of road construction and maintenance actually prepare the district office's draft annual budget for and submit it to the regional offices. Regional offices assess and adjust them to keep the overall balance for preparation of the regional office's draft annual budget. The headquarters assesses and adjusts the regional office's draft annual budgets to keep the overall balance for the preparation of the DRR overall budget to be submitted to MOT. After MOT decides the DRR annual budget, DRR headquarters allocates the budget for regional offices and regional offices allocate it to provincial offices.

According to the director of a regional office, although the road construction budget is increasing gradually each year, the road maintenance budget is not increasing as much as the road construction budget, and the required budget is about double the present budget.

The maintenance budget is classified into, routine maintenance, periodic maintenance, special maintenance and emergency maintenance. The routine maintenance budget is spent on daily inspection and maintenance work, the periodic maintenance budget is spent on periodical maintenance such as overlaying asphalt on the road surface and the work in this category is all contracted out. The special maintenance budget is spent on larger work than periodical maintenance work, for example, replacement of asphalt surface layer. The routine maintenance budget is determined by the length of the road maintained, and it is 30,000 baht per two lanes per km in 2014. As for the periodic budget, each project is estimated by the

provincial office. After submission of the draft budget for the periodic maintenance, the headquarters gives instructions to the regional office to carry out the Benkelman beam test for the sites to understand the road conditions. The regional office or the provincial office carries out the Benkelman beam test and sends the test results to the headquarters for assessment. In addition, both the regional offices and the provincial offices use the PMMS database for the cost estimation of the project.

Figure 61 Image of Benkelman Beam Test

2) Implementation (Do)

The roles of inspection and maintenance are divided amongst headquarters and the regional bureaus as follows.

Work category	Responsible
Road surface condition survey	Headquarters
Control of the PMMS	Headquarters
Inspection and maintenance of roads	Regional bureau
Inspection and maintenance of long bridges in Bangkok Metropolitan Area	Headquarters
Inspection and maintenance of conventional bridges	Regional bureau

DRR developed a road survey car called the Rosy Car in collaboration with Chularongkorn University. DRR owns five Rosy Cars which are equipped with digital cameras and a GPS sensor for measuring IRI. DRR has a plan to procure another three Rosy Cars. DRR concentrates on data accumulation so that the data can be more effectively utilized in management.

Figure 62 Rosy Car

3) Evaluation (Check)

Three kinds of systems, PMMS: Pavement Maintenance Management System, RMMS: Routine Maintenance Management System, CRD: Central Road Databank are used for the maintenance work.

As for bridges, BMS was constructed in 2013 by JICA's technical assistance and JICA also conducted the preparation of an inspection manual and technical training so that DRR staffs are able to inspect and collect data by themselves. After the JICA project was completed, DRR collected inspection data on two thousand bridges and input the data into the BMS by employing a consultant for inspection data. The inspection method was basic, involving a visual inspection, and the unit price was 7,000 baht per bridge. DRR plans to complete the inspection and input them into the database for the remaining 6,000 bridges within three years.

Regarding the meeting system, the main meeting in DRR is executed every week by teleconference with the attendance of all directors of regional bureaus.

(3) Condition of Regional Bureau

The condition of a regional bureau located near Bangkok metropolitan area is described.

1) General Information

Regional Bureau No.1 is responsible for 16,000 km of 2–lane roads, and 90% of the total length is asphalt pavement, 10% is concrete pavement and a very short length, only 40 to 50 km, is laterite road. Although the unit cost of concrete pavement nearly double that of asphalt pavement, concrete pavement is often used in communities where it is difficult to conduct maintenance because of the advantage of the longer lifespan of concrete pavement.

In a provincial office, there are 10 to 20 permanent staff, 10 to 20 temporary staff and 10 to 20 casual workers, for a total of 40 to 50 staff. The total number of staff of regional bureau No. 1, which oversees five provincial offices, is approximately 300 staff including 50 staff working in the regional office. The role of staff in the provincial offices is not divided and every staff does most work such as construction, inspection and maintenance work. The provincial offices also own construction equipment, other equipment and vehicles.

2) Plan

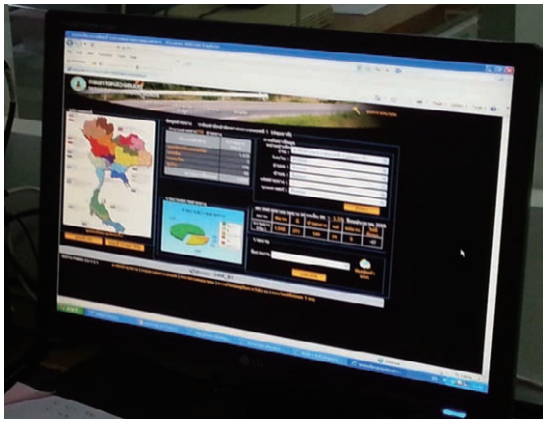
The regional office prepares the three years mid-term plan, and the provincial office prepares yearly, quarterly, monthly and weekly plans.

3) Implementation (Do)

Inspection and Maintenance

The provincial office staff use their equipment to conduct construction, inspections and maintenance of roads. There are standard road inspection sheets and bridge inspection sheets, and DRR started a trial use of tablets for road inspection instead of inspection sheets in some regional bureaus from 1st August, 2014. Therefore, the inspection sheet is not used in regional bureau No.1.

As for PMMS, the regional bureau and provincial office are in charge of data input for CRD.



Homepage of PMMS

Photos of sites are stored in PMMS

The provincial offices carry out bridge inspections based on the bridge inspection sheet and store them in the BMMS, and report it to the headquarters only when they find problems. The headquarters directly deals with the BMMS constructed with JICA's assistance. It can be understood that the method of inpecting bridges is currently in a period of transition to a new system.

Plan, Design and Database

There is a Research and Design Office in Regional Bureau No.1 where two permanent staff and four temporary staff work. The Research and Design Office conducts site surveys, traffic volume surveys, design, cost estimation, preparation of tender documents, verification of status of warranty of the past works, etc. The Research and Design Office fully utilizes the PMMS through execution of these works. The data stored in the PMMS are mainly length of each road segment, construction and repair history, traffic volume, site photos, site survey reports, etc. and this data is used to plan staff numbers and to estimate project costs. In addition, the Research and Design Office is able to surely update the drawings of each road segment because this office prepares drawings and does the procument of the work. Although many drawings are sill kept in a paper format, all drawings prepared recently are stored in digital format. All six staff are able to utilze the PMMS and Auto CAD.

The PMMS which is a simple database, not a GIS system, is fully utilized daily in the regional bureau. The PMMS is one module of CRD and we have to log into CRD first to use the PMMS. The provincial office only has access to data within its jurisdiction and they utilize the PMMS daily.

4) Evaluation (Check)

Two kinds of meeting held in the regional bureau, one deals with technical agendas and the other deals with administrative agendas. The technical meeting is to understand the progress made and problems faced by each provincial office, and to discuss how to overcome problems to achieve the planned targets. The annual plan shows the targets for progress each month with respect to road length (km) and costs, as well as the actual progress so as to monitor the difference.

The administrative meetings are held in provincial offices in turns so that administrators in the provincial offices can learn how the other provincial offices operate.

(4) Bridges

Since the establishment of DRR in 2002, the construction of new bridges in Bangkok metropolitan area is implemented by the Bangkok Metropolitan Administration (BMA) and MOT provides BMA with subsidies amounting to 40% of the total cost. DRR is in charge of maintenance of bridges in Bangkok metropolitan area constructed before 2002 and construction and maintenance of bridges outside of Bangkok metropolitan area owned by DRR.

Many guidelines and manuals which had existed in DRR were properly arranged through JICA's technical cooperation, and they are used at present.

In the maintenance department, there are groups for administration, planning, maintenance system, road maintenance, and bridge maintenance. The bridge maintenance group is in charge of three steel truss type brides and seven PC-type box girder bridges crossing Chao Phraya River, while Bureau of Bridge Construction is in charge of cable-stayed type bridges. In addition, there is a Bridge Inspection Division specializing in inspection of bridges in rural areas.

(5) Technical Cooperation by JICA

DRR received the JICA's technical cooperation recently.

a) Bridge Maintenance Plan Survey (Chao Phraya River Bridge) in Thailand, 2011

- Inspection of 12 bridges crossing Chao Phraya River to understand the present condition
- Formulation of maintenance plan for the 12 bridges
- Recommendations on a maintenance system to DRR
- Technical Transfer on bridge maintenance

b) The Project for Bridge Master Plan and Bridge Maintenance Ability in Rural Areas, 2012

- Preparation of the inspection and maintenance plan for 8,000 bridges and implementation of a pilot project of bridge inspection.
- Assisting DRR to establish Bridge Maintenance Management System (BMMS)
- Implementation of seminars, workshops and training courses
- Reviewing the bridge master plan prepared by DRR and preparing suggestions

(6) Assessment of Present Condition of Asset Management and Issues

The present condition of asset management of DRR is similar to that of DOH. In the field of asset management in terms of engineering and economics, which are the cornerstone of infrastructure management, DRR is currently working very hard to strengthen the inspections and to strengthen its database. After this has had time to develop and be strengthened to a certain extent and the accuracy of the data can be ensured, a point will be reached whereby it can be used to strengthen economic management such as through LCC analysis. DRR is aware that it is at the stage of moving on to economic management and expects to receive the technical assistance for this purpose.

To achieve the implementation of management with an important long-term perspective, it is necessary for the outcome of these current efforts to appear to some extent and, in addition, for the planning and coordination functions of various internal organizations to be strengthened.

4.4.4 Expressway Authority of Thailand (EXAT)

(1) General Information

1) Road conditions

EXAT is responsible for construction and maintenance of expressways within Bangkok metropolitan area and its environs. As of 2014, EXAT manages eight expressway routes, 207.9 km in total, and two routes out of eight routes are operated and maintained by concessionaires, Bangkok Expressway Public Co., Ltd. (BECL) and Northern Bangkok Expressway Co., Ltd. (NECL) by Built-Transfer-Operate contract. Therefore, the total road length directly maintained by EXAT is 137.9 km and 38.4 km by BECL and 32 km by NECL.

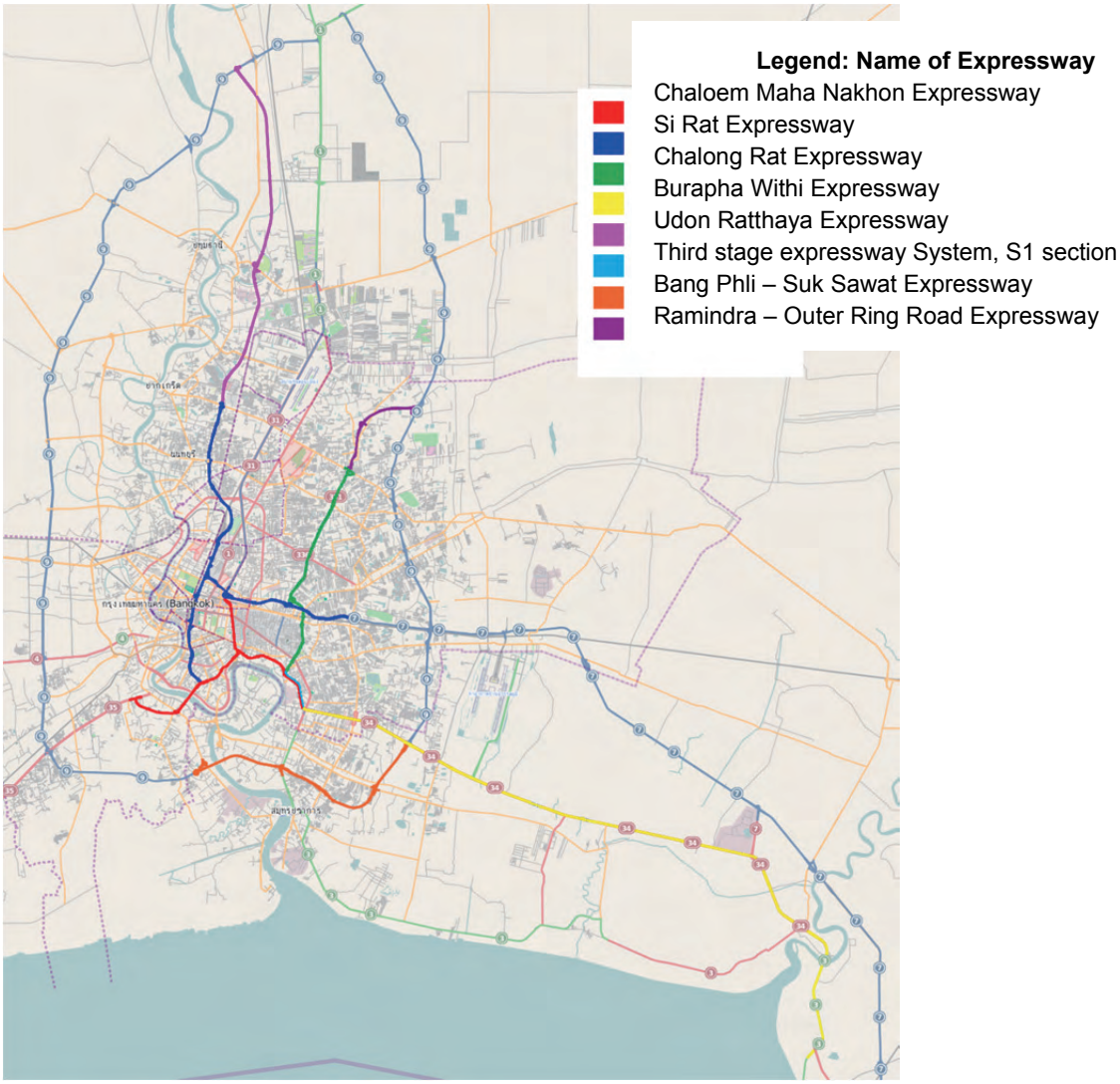


Figure 63 Map of Expressways Managed by EXAT

Source: OpenStreetMap image

Table 47 List of Expressways Managed by EXAT

No	Name of Road Route	Service year	Road Length (km)	Organization
1	The Chaloem Maha Nakhon Expressway			
1a	Din Daeng Port section	1981	8.9	EXAT
1b	Bang Na Port section	1983	7.9	EXAT
1c	Dao Kanong Port section	1987	10.3	EXAT
2	The Si Rat Expressway			
2a	Ratchadapisek Road passing Phayathai Interchange and Rama IX Road	1993	12.4	BECL
2b	Payathai Interchange to Chaloem Maha Nakhon Expressway	1996	9.4	BECL
2c	Rathcadapisek Road to Chaeong Watthana Road	1993	8.0	BECL
2d	Rama IX Road to Sri Nagarindra Road	2000	8.6	BECL
3	The Chalong Rat Expressway			
3a	Ram Inthra at KM 5.5 to Narong	1996	18.7	EXAT
3b	Ram Inthra Road linking to Outer Ring Road connecting to Chalong Rat Expressway	2009	9.5	EXAT
4	The Burapha Withi Expressway	2000	55.0	EXAT
5	The Udon Ratthaya Expressway	1999	32.0	NECL
6	The Bang Na-At Narong Expressway	2005	4.7	EXAT
7	The Bang Phli-Suk Sawat Expressay	2007	22.5	
8	The Access Road linking Bang Phlisuk Sawat Expressway to Burapha Withi Expressway and Outer Bangkok Ring Road			
9	The Elevated Access Road in the South of Suvanabhuri Airport linking with the Burapha Withi Expressway			
	Total road length owned by EXAT		207.9	
	Total road length maintained by EXAT		137.5	

Source: prepared by Study Team referring to EXAT's information

The figure shows the classification of EXAT expressway by the service years, and it shows 16.8km (8%) is more than 30 years, 27.1km (13%) between 20 to 30 years, and 124km (61%) between 10 to 20 years and 36.7km (18%) is less than 10 years. EXAT expressway is understood to be rather new generally.

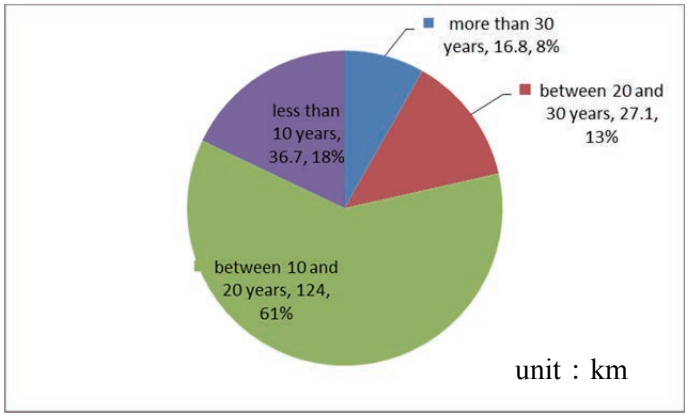


Figure 64 Classification of EXAT Expressways by Service Years

Source: Prepared by Study Team

Most parts of EXAT expressway is elevated bridge type and very short parts is embankment and there are two long span cable-stayed bridges.

Table 48 Main Information of Cable-Stayed Type Bridges in EXAT Expressways

Name of bridge	Rama 9 Bridge	Kanjanapisek Bridge
Structural type	Cable-stayed type	Cable-stayed type
Crosses	Chao Phraya River	Chao Phraya River
Number of lanes	3 lanes times x 2	4 lanes x 2
Total length	781.20 m	941m
Width	33m	36.7m
Pylon height	87m	187.6m
Longest span bridge	450m	500m
Clearance	41m	-
Service started	1987	2007

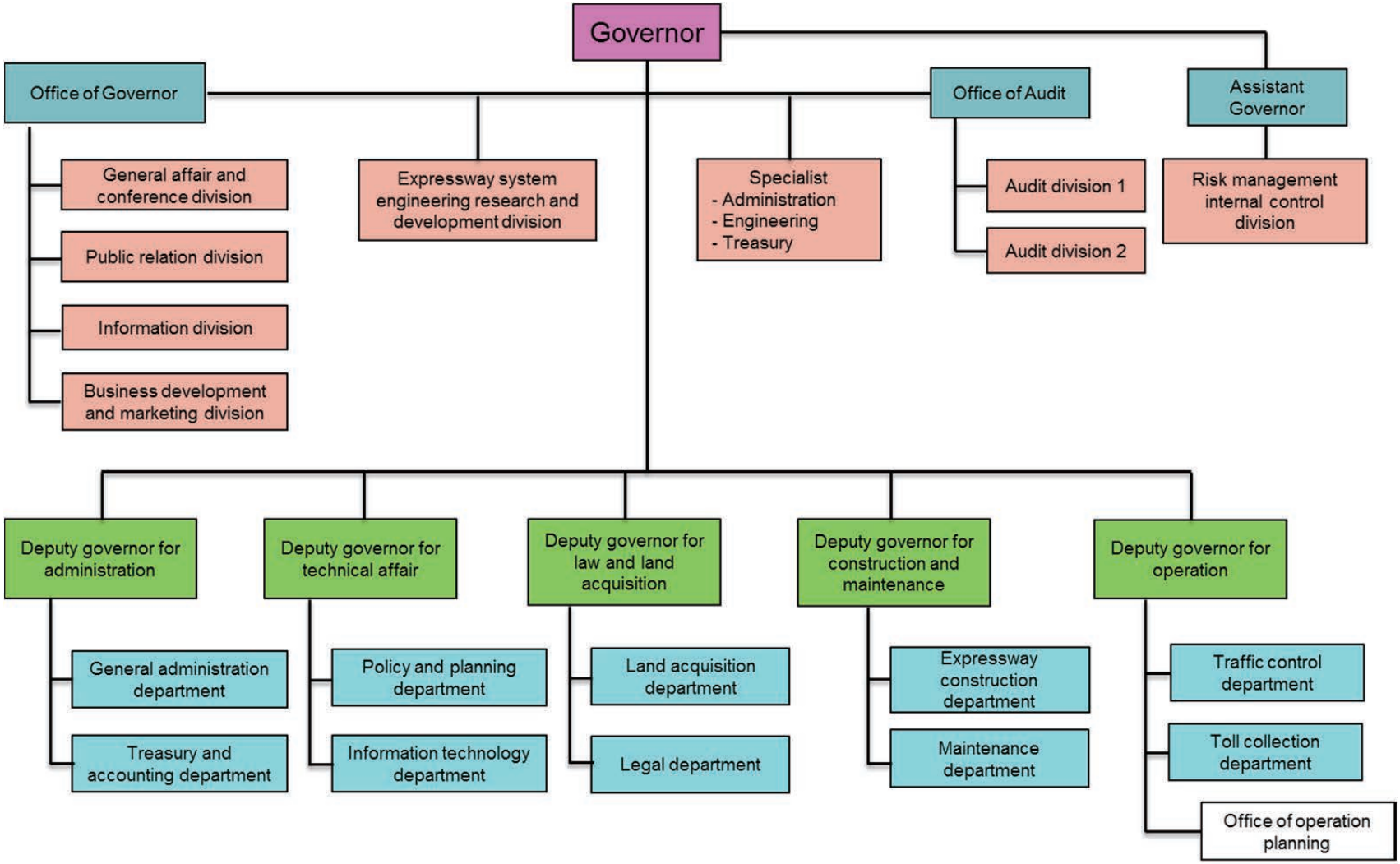


Figure 65 EXAT Organization Chart (Source: EXAT Annual Report 2013)

2) Financial condition

The number of expressway users has increased by more than 5% yearly, even though the total length of expressway has been constant since 2009.

Table 49 Trends of Length of Expressway and Number of User Cars, 2008 to 2013

	2009	2010	2011	2012	2013
Total service covering length (km)	207.9	207.9	207.9	207.9	207.9
Traffic Volume (million trips /day)	1.24	1.31	1.42	1.52	1.61
Trips Increase from last year	11.7%	5.9%	8.1%	7.4%	6.1%

Source: EXAT Annual Report, 2013

This increase in users has resulted in an increase in the total revenue every year, and also led to an increase in the net profit, with the net profit by revenue reaching 45% in 2013.

Table 50 Trends of Income Statement Results, 2008 to 2013

Unit: Mill baht

Item	2,008	2,009	2,010	2,011	2,012	2,013
Total Revenue	6,036	7,600	8,918	12,096	12,902	14,516
Total Expense	4,794	5,038	5,832	6,575	7,059	7,927
Net Profit	1,242	2,561	3,086	5,521	5,842	6,589
Net Profit/Revenue	21%	34%	35%	46%	45%	45%

Source: EXAT Annual Report, 2013

Most of EXAT assets are fixed assets, which is composed of half land and half expressway. The liabilities are decreasing as debt is gradually repaid, and on the other hand, capital is increasing as the profit is accumulated as capital every year.

Table 51 Trends of Balance Sheet, 2008 to 2013

Unit: Mill baht

Item	2008	2009	2010	2011	2012	2013
Current Assets	6,684.97	6,744.44	8,200.18	9,316.92	7,968.78	6,776.81
Fixed Assets	162,825.99	166,632.26	167,209.37	170,692.78	170,315.97	170,612.68
Other Assets	17,092.10	16,091.91	14,484.90	5,599.77	4,944.47	4,353.97
Total Assets	186,603.06	189,468.61	189,894.45	185,609.47	183,229.22	181,743.46
Total Liabilities	103,849.75	97,037.31	91,615.76	94,413.00	87,696.93	79,800.42
Total Equity	82,753.31	92,431.30	98,278.69	91,196.47	95,532.29	101,943.04
Total Liabilities & Equity	186,603.06	189,468.61	189,894.45	185,609.47	183,229.22	181,743.46

Source: EXAT Annual Report, 2013

Table 52 Breakdown of Tangible Fixed Assets, as of the end of September 2013

Unit: Mill baht

Item	Cost	Accumulated depreciation	Net book value	Depreciation period
Land	79,889.97	0.00	79,889.97	-
Expressway	108,630.11	20,995.03	87,635.08	75 years
Building	1,802.17	681.65	1,120.52	5-40 years
Office tools	1,261.72	906.83	354.89	5 years
Engineering equipment	129.98	92.45	37.53	5 years
Vehicles	739.32	477.27	262.05	5-15 years
Total	192,453.27	23,153.23	169,300.04	

Source: EXAT Annual Report, 2013

By analyzing EXAT's 2013 financial indices, earning power is high as the net profit ratio is 45%. Savings for investment for replacement of infrastructure facilities[59] shows that savings is about 40% of the accumulated depreciation expenses as cash flow from investing activities and cash and cash equivalent is 38% of accumulated depreciation and amortization expenses. The level of deterioration does not seem to be serious for only 12% of costs of fixed asset are already depreciated. This is due to the fact that about 40% of the cost is land, which does not depreciate, and the depreciation period of expressways, which is the other main asset, is as long as 75 years, but still many fixed assets are considered to be relatively young.

Table 53 Major Financial Index

Assessment item	Index	2013
Earning power	Net profit ratio	45%
Savings for investment for replacement	Cash to be used for investment for replacement / accumulated depreciation and amortization expenses	38%
Level of deterioration	Accumulated depreciation / cost of fixed asset	12%

Seemingly, EXAT has a strong earning power and facilities are still young. Savings for investment is enough for the moment.

Budget for maintenance and repair is allocated as requested and is increasing every year so far. It accounts for 8-9 % of the total expenditure.

Table 54 Trend of Maintenance Costs

Unit: Mill baht

Item	2011	2012	2013	2014	2015
Maintenance, Labor cost	209	237		294	304
Civil work Maintenance, Labor cost	41	41	-	53	53
Maintenance, Expense	290	374		467	532
Civil work Maintenance, Expense	21	33	-	26	37
Total Maintenance Budget	499	611	ni	761	836
Total Expenditure	6,575	7,059	7,927	9,237	9,413
Maintenance cost / Total expenditure (%)	8%	9%		8%	9%

Source: EXAT

[59] Cash to be used for investment for replacement / accumulated depreciation and amortization expenses, Cash to be used for investment for replacement = cash flow from investing activities + cash and cash equivalents + current investment

EXAT expects the following revenue and expenses up to 2018. Based on the past performance, the total revenue is expected to increase by 4% and total expense by 3%.

Table 55 Forecast of Revenue and Expense

Unit: Mill baht

Item	2014	2015	*2016*	*2017*	*2018*
Total Revenue	15,116	15,826	*16,390*	*16,851*	*17,288*
Total Expense	9,237	9,413	*9,658*	*9,945*	*10,236*
Net Profit	5,878	6,414	*6,732*	*6,905*	*7,053*
Net Profit/Revenue	39%	41%	*41%*	*41%*	*41%*

Note: Numbers for 2014 and 2015 are budget, and 2016 -2018 are forecast.

Source: EXAT

(2) Implementation (Do)

1) Organization

There are following four units under Maintenance Department.

- Expressway maintenance division
- Building and general property maintenance division
- Equipment maintenance division
- Equipment and mechanical equipment and vehicle division

Expressway maintenance division is a main responsible unit for maintenance work and each sub-unit is responsible as follows.

Table 56 Role of Each Sub-Unit of Expressway Maintenance Division

Name	Role
Maintenance Planning Section	Inspection and maintenance of sub-structures of elevated bridges
Inspection and Maintenance Section 1	Inspection and maintenance of super-structures of elevated bridges
Inspection and Maintenance Section 2	Inspection and maintenance of super-structures of elevated bridges
Bridge Maintenance Section	Inspection and maintenance of bridges

2) Inspection

The inspections carried out by EXAT are classified into three categories.

Daily inspection

The daily inspection involves checking the condition of expressway components such as the deformation of the road surface joints, cracking of retaining walls, distortion of steel rails, traffic signs, electric lighting, malfunctions in the operation of the toll collection device, emergency telephone system and CCTV on a daily basis.

Both Inspection and Maintenance Sections carry out inspections of pavements and parapet walls and so forth on a daily basis. Each team carries out the inspection work for 10 km per day using a special vehicle with inspection forms, a measurement tape, spray paint, a digital camera, a skid resistance meter, etc.

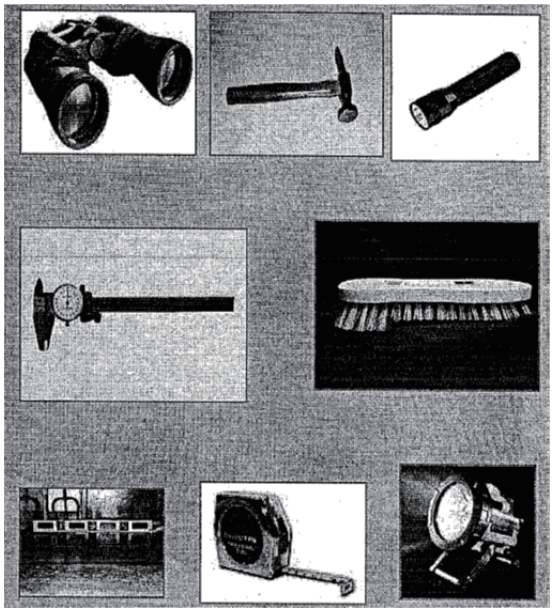


Figure 66 Tools Used for Daily Inspection

Source: EXAT

Routine inspection

This involves regular inspections of the main structure of the expressway such as cracks, cracking of the concrete structure, condition of the steel nuts, steel structure, inspection of the wire mesh of the Rama 9 bridge structure, deterioration of traffic signs, reflective pins, transformer equipment condition, intensity of the electricity of expressway, toll collection devices and CCTV according to the planned schedule each year.

Both Inspection and Maintenance Sections carry out routine inspections daily for one kilometer with binoculars on foot using some tools such as inspection forms, a measurement tape, a digital camera, binoculars, vehicles, lighting, hammer, etc.

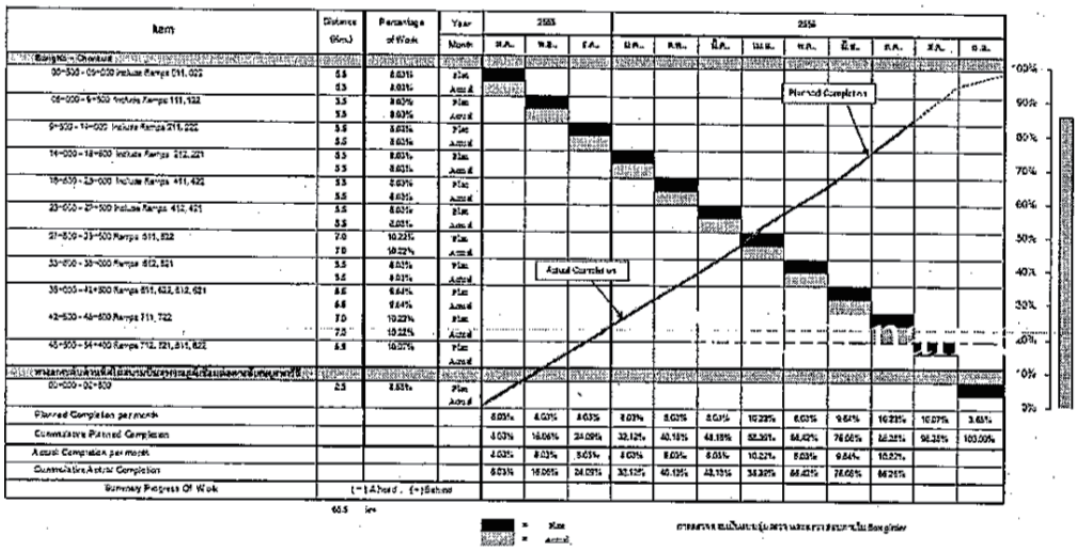
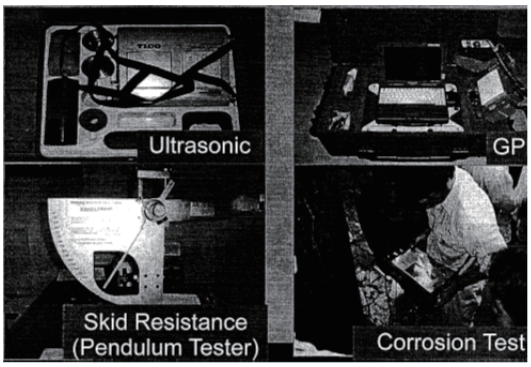


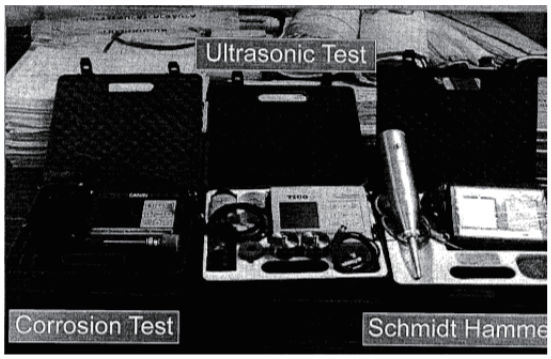
Figure 67 Yearly Inspection Schedule

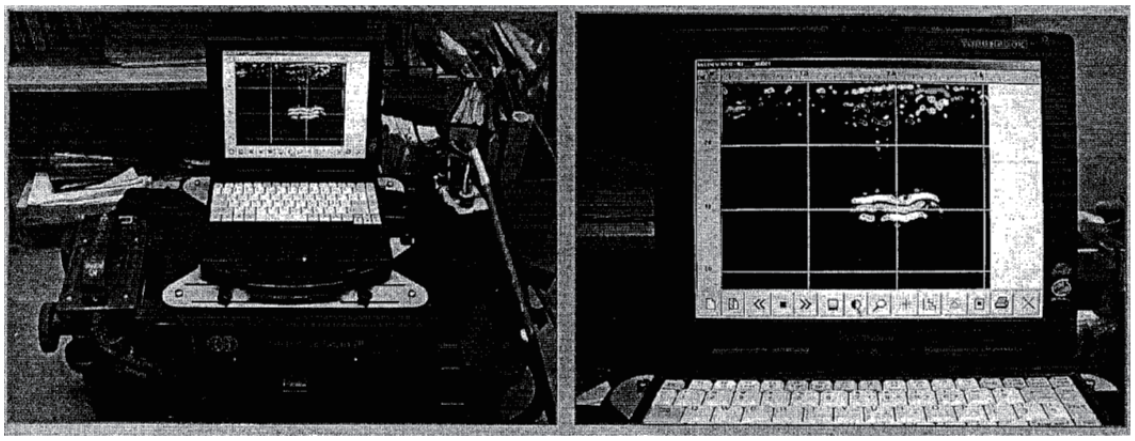
Special inspection

This is a more detailed inspection of the structure of expressways in addition to the daily inspection and routine inspection, which involves:

- Testing the alkalinity of the concrete structure using Carbonation Test
- Corrosion Test
- Inspection of fracture using Ultrasonic Test
- Skid Resistance Test
- Inspection of the condition of the cavity using Ground Penetration Radar
- Inspection on the strength of the Rama 9 bridge structure







Ground penetration radar

Figure 68 Tools Used for Special Inspection

Source: EXAT

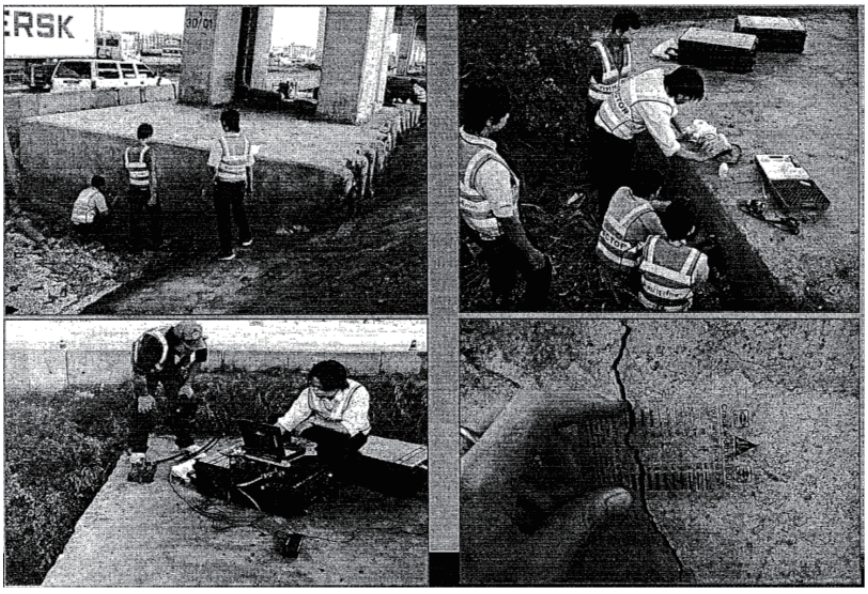


Figure 69 Inspection of Foundations of Viaduct

Source: EXAT

3) Expressway maintenance and repairs

Maintenance and repairs were conducted in the following three aspects

- Routine maintenance, including cleaning of traffic signs, road signs, the surface drainage system, lighting lamps, changing of road signs, painting of steel rails and small repairs on a regular basis according to the planned schedule.
- Corrective maintenance is depending on the actual damage, such as the repairs to the road surface, road surface joint, retaining wall joints, seal cracks on concrete structures, replacement of bulbs, electric light wires, repair of toll collection devices, emergency phone system, VMS and damaged Matrix Sign.

- When urgent maintenance is required for the damage from incidents such as damage caused by accident, fire, chemicals and so on, the initial emergency maintenance will be conducted. The purpose of this is to rapidly allow the expressway to be used again until permanent repairs/maintenance of the damaged structure and component of the expressway can be undertaken.

Currently, the maintenance works such as the following are carried out.

- Water proof painting has been introduced for parapet wall of elevated bridges constructed at the initial period since around 1990.
- The joints of elevated bridges which are easily damaged are repaired whenever necessary.
- Cracks in concrete are repaired by the appropriate method depending on the damage condition and the cause of damage.
- Small parts of peeling of concrete have started to occur.
- Ruts on road pavement are repaired by laying polymer modified asphalt after removing the surface asphalt layer.
- When the roughness coefficient of the road pavement goes below the requirement, slurry seal of 8 mm thickness is applied on the surface.

EXAT has implemented various maintenance projects as follows.

A. Projects completed between 2008 and 2014

Electrical and system maintenance

- The relocation and installation of high-mast lighting poles on Chalong Rat Expressway at the Artnarong 2 toll station.
- Maintenance of the electrical lamp of Chalerm-Mahanakorn Expressway and Burapawitee Expressway.
- Network system improvement of Burapawitee Expressway.
- Improvement of road surface on expressway to extend the service life and safety.
- Improvement of the slopes of the on- and off-ramps of the Chalerm-Mahanakorn Expressway and Burapawitee expressway to reduce the impact of vehicles as a result of the settlement of the soil.
- The restoration of road surface including joints on the Chalerm-Mahanakorn Expressway at the Wat Saphan Soong area.
- Plaster road surface with Para Slurry Seal to add friction to the road surface of Chalerm-Mahanakorn Expressway from Wat Saphan Soong high-level bridge pier and the Chalong Rat Expressway at Rama 9 - ArtNarong.

Increase safety and reduce accidents

- Installation of reflective glass bead pins to enhance visibility in the rain on Chalerm-Mahanakorn Expressway, Chalong Rat Expressway and Buraphwitee Expressway.
- Installation of flashing lights on the off-ramp traffic islands of Chalerm-Mahanakorn Expressway, Chalong Rat Expressway and Buraphwitee Expressway.

Social and environmental responsibility tasks

- Installation of noise barriers on Chalerm-Mahanakorn Expressway to minimize the impact on teaching and learning in Poonsin school.
- Support the community to prevent fires in communities near the Chalermmahanakorn Expressway.
  - ✧ Project to install fire water dispensers in six areas
  - ✧ Project to purchase fire extinguishers in 12 areas (in the process of delivery to the community).

B. Projects in progress

Electrical and System Maintenance

- To cover underground wires of the Burapawitee Expressway by concrete.
- The concrete shielding conduit and installation of set off boxes of the safety switches on the Burapawitee Expressway.
- Repair and maintenance of electrical power high mast lighting on Chalong Rat Expressway and lights under the expressway of Burapawitee Expressway.
- Installation of automatic toll collection system on Chalerm-Mahanakorn Expressway, Chalong Rat Expressway, Ram Intra Expressway - Rings - Outer Bangkok Expressway and Burapawitee Expressway.
- Improvement of the speed limit sign (Matrix Sign) on Chalong Rat Expressway.
- Improvement of the traffic condition monitoring system.

Improvement of road surface on expressway in order to extend the service life and safety

- The restoration of road surface including joints on Chalerm-Mahanakorn Expressway.

Tasks to increase safety and reduce accidents

- Improve the brightness of traffic signs to increase their visibility from 15 to 30 meters on Chalerm-Mahanakorn Expressway, Chalong Rat Expressway and Burapawitee Expressway.
- Improve the visibility of traffic signs on Chalerm-Mahanakorn Expressway.
- Installation of Crash Cushion equipment in three areas (expected to be completed by April 2009).

Other engineering maintenance

- Change U shape rib stiffener of Rama 9 Bridge
- Exterior paint restoration of the Rama 9 bridge structure as it had been used for over 10 years.
- The restoration of joints for flexibility and expansion of the Rama 9 bridge to extend the working life.
- Contracting AIT to study methods of strengthening the foundations of Burapawitee Expressway.

Social and environmental responsibility tasks

- Installation of noise barriers on Chalerm-Mahanakorn Expressway to reduce the impact on residents near the expressway around the Rama 4 to Tahrue 2 Expressway.

(3) Evaluation (Check)

The inspection manual prepared in 1994 by JICA's technical assistance was revised by AIT in 2001. AIT also has provided the inspection training to staffs in EXAT. The assessment of the inspection was rated in four grades: Very good (D), Good (C), Fair (B), Poor (A), and the assessment rating is explained with photos using the inspection manual. After the inspection, the budget is allocated for the parts which gained the worst rate, and the budget is sufficiently allocated for the maintenance and repair work.

The inspection and maintenance work is a main work for EXAT because no new expressway section has been constructed since 2010. As for the road management system, ETAMS constructed by JICA's technical assistance has been used since 1994 and the inventory data has been arranged and however the system to assist for examining the maintenance and rehabilitation plan is not ready.

At present, EXAT has been researching and developing BMS for viaduct structure. In addition EXAT has started to develop a management system to increase value for money (VFM) in collaboration with Chularongkorn University.

(4) Inspection and Maintenance for Rama IX Bridge

The maintenance for Rama IX Bridge, which entered into service in 1987, is very carefully implemented because this is the first cable stayed bridge in Thailand.

The detailed maintenance manual was prepared by JICA's technical cooperation in 1994, and it was revised in 2001. The 10 year periodical inspection was implemented in 2001 and 2011 and the maintenance was implemented in accordance with the maintenance work plan prepared based on the inspection results. The main maintenance activities are described below.

Year	Activities done
1987	The bridge entered into service
1994	JICA team formulates the maintenance manual
1995	The monitoring device was installed at the bridge
2001	The maintenance manual was revised. The 10-year periodical inspection was implemented
2003	The maintenance and repair work was commenced in accordance with the inspection results
2007	Cables and pylons were re-painted
2009	Deck floor was re-painted
2011	The 2nd 10-year periodical inspection was implemented.

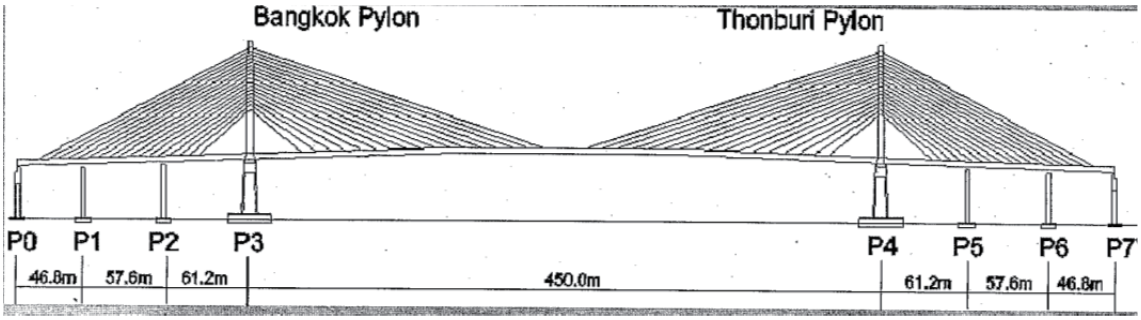


Figure 70 Elevation Plan of Rama IX Bridge

Bridges maintenance section is in charge of two cable-stayed type bridges, Rama IX Bridge and Kanchanapisek Bridge, which both cross Chao Phraya River.

(5) Recent Technical Cooperation by Japanese Organization

1) Technical cooperation by JICA

The inspection and maintenance manual for Rama IX Bridge was prepared in 1994 when JICA conducted the inspection and maintenance plan for expressways in Thailand. Since then, the manual has been revised.

2) Technical cooperation by NEXCO

EXAT has signed two memorandums of technical cooperation with three companies of Japan to receive technical assistance from these companies.

■ West Nippon Engineering NEXCO Chugoku Co., Ltd.

Signed a memorandum of understanding in April 2010.

Scope

- ETC system
- Traffic control system: traffic information system, traffic control system, ITS, etc.
- Maintenance of expressways including bridges
- Exchange of experts and training

■ Metropolitan Expressway Co. Ltd. and Hanshin Expressway Co., Ltd.

Signed a memorandum of understanding in April 2010.

Scope

- ITS system including traffic control system
- Maintenance of expressway including bridges
- Exchange of experts and training

According to an expert of Metropolitan Expressway Co., Ltd., Metropolitan Expressway Co., Ltd. received about 70 staff from EXAT, BECL and NECL in Japan for technical training and conducted site visits and technical lectures. In this programme, Metropolitan Expressway Co., Ltd. covered training costs and EXAT covered transportation and accommodation costs.

(6) Condition of Facilities

1) Concrete viaduct

The condition of concrete structures is assessed to maintain very sound conditions according to the highway expert in the Bangkok Office of Metropolitan Expressway Co., Ltd. This is due to not only the relatively young age of the structure but also the following.

- Calcium Chloride which is spread to melt snow on roads has never been spread on roads because it never snows in Bangkok.
- There is almost no salt damage to concrete by sea breeze, because Bangkok is far enough away from the coast.

- Since the temperature difference is small throughout the year, the amount of shrinkage of concrete is small. Therefore, cracking hardly occurs, and the expansion joints of viaduct which are generally damaged easily are not damaged very often. Furthermore, it is easy to maintain the expansion joints, because it is possible to adopt a joint of a simple structure.

2) Steel Bridges

Rama IX Bridge is a very important bridge for Thailand because it is the first cable-stayed type bridge in Thailand and also the King's name has been given to the bridge. Therefore, the maintenance has been very carefully implemented. As for Kanjanapisek Bridge, the maintenance know-how gained through the maintenance of Rama IX Bridge has been fully applied.

(7) Assessment of Present Condition of Infrastructure Management and Issues

There is little work such as cleaning and grass cutting in maintenance of EXAT expressway because the most segments consist of RC elevated bridges. RC structures are generally in sound condition as they are relatively new, and the main maintenance work currently carried out are only for road pavement and joints. Therefore, the required maintenance work at present is relatively little and the priority of maintenance for EXAT is not high.

The maintenance budget of 836 mill baht in 2015 is not large amount for EXAT's operation. However, the required budget amount has been fully approved so far and the required budget amount is little due to new facility.

However, the required maintenance budget is gradually increasing and this is due to inflation and the increase of required repairs with progress of aging in facilities. Aging of facilities will surely progress and it will lead to an increase of required maintenance work. This is an important issue for EXAT because EXAT has little experience with maintenance of RC structures.

EXAT maintains only 137.9 km out of 207.9 km of expressway and the remainder is maintained by concessionaires. The proposed expansion routes are planned to be done by PPP also, therefore the routes maintained by EXAT are not expected to increase much. However, it is an important issue for EXAT to supervise concessionaires to surely maintain expressways.

4.4.5 Public Works Department of BMA

(1) General Information

BMA's jurisdiction area is the entire Bangkok metropolitan area, which is approximately 1,600km². BMA is responsible for 28.97 million m^2 of road, 1,080 canal bridges, 48 flyovers, three viaducts, one bridge crossing a river, 607 pedestrian bridges and 12 underpasses. Construction and Maintenance Office of BMA maintains these facilities with 1,286 staff.

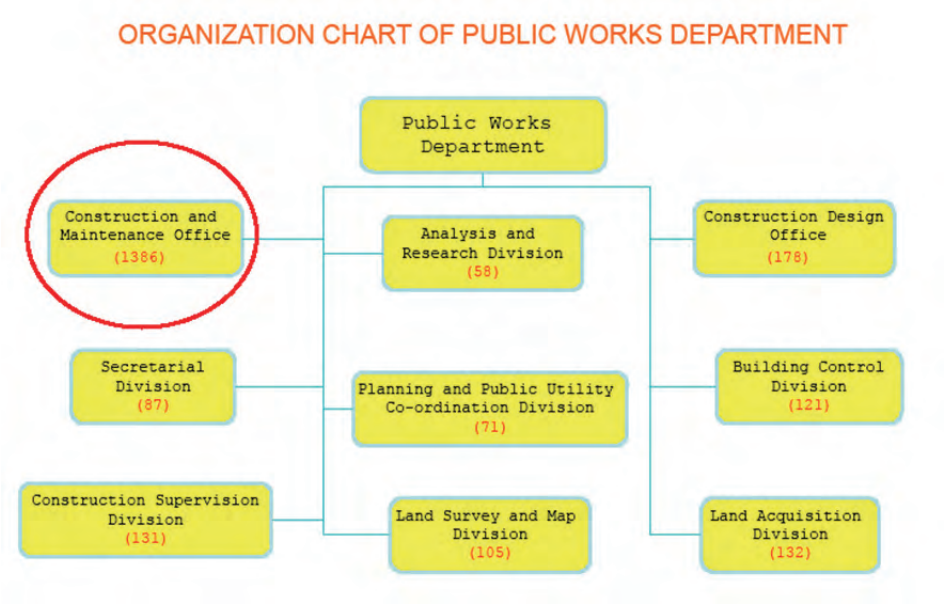


Figure 71 Organization Chart of Public Works Department of BMA

(2) Pavement

The inspection of pavements is carried out only visually and the maintenance work is generally only carried out in response to complaints from members of the public to BMA's complaint phone number 1555 in the Public Works Department. Therefore, this is a corrective maintenance system, however this system is common for municipal roads in Japan.

BMA conducted a trial road surface condition survey of 2,500 km of road in 2011, however the data has not been used because a heavy flood occurred immediately after the survey.

Though BMA does not have a PMS as yet, BMA has prepared tender documents for a PMS using GIS and it will be tendered soon.

(3) Bridges

In Bangkok there are 1,080 bridges crossing canals and they are essential infrastructure for people's life and economic activities, and many of these bridges are too difficult to be

replaced even though they are seriously deteriorated due to heavy traffic and limited space. Therefore, BMA has been greatly endeavoring to inspect and maintain such bridges. BMA classifies the inspection and maintenance as follows and all data are stored in the bridge database.

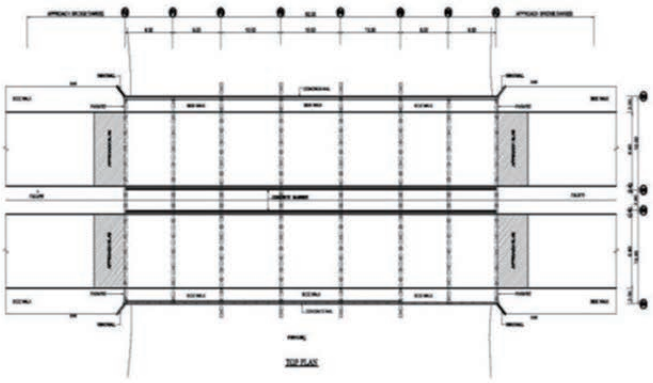
- Visual inspection
- Material testing
- Inspection of foundations
- Evaluation
- Repair
- Reinforcement

1) Visual Inspection

The inspection staff carry out the visual inspection according to the bridge inspection sheet, and store the inspection data including the bridge location, drawings, site photos, etc. in the bridge database so that the bridge engineers are able to diagnose the damage and to design properly in the office.

Figure 72 Bridge Site Location Shown in the Database

Basic Information (LT, RT)	
Type	Slab Type
ขนาดความยาวสะพาน (ม.)	ST(2x8.00)+ST(3x10.00)+ ST(2x8.00)
Overall length (m.)	62
Bridge width (m.)	2x9.60
Side walk (m.)	2.00
No. of Lanes	2x3
Surface Material	Concrete



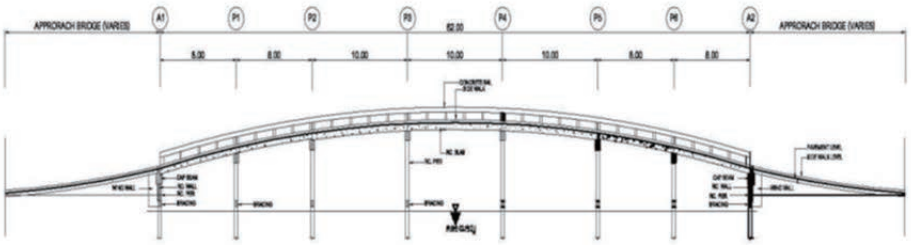


Figure 73 Basic Information of Bridge Shown in the Database

Figure 74 Site Photos of Damage Shown in the Database

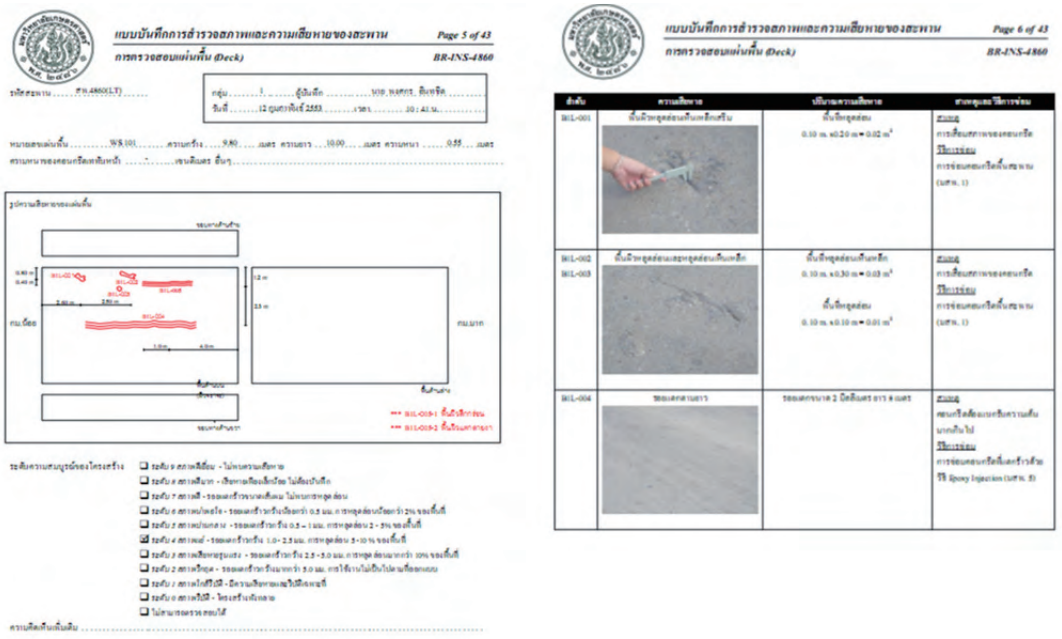


Figure 75 Example of Bridge Inspection Report

The damages of bridges are rated based on National Bridge Index (NBI) System as shown below.

NBI Ratings

Concrete Deck Condition Rating (Item 58)

Code	Condition of Deck Item
N	Use for all culverts
9	**Excellent condition** – No noticeable or noteworthy deficiencies which affect the condition of the deck item. Usually new decks.
8	**Very good condition** – Minor transverse cracks with no deterioration, i.e. delamination, spalling, scaling or water saturation.
7	**Good condition** – Sealable deck cracks, light scaling (less than ¼" depth). No spalling or delamination of deck surface but visible tire wear. Substantial deterioration of curbs, sidewalks, parapets, railing or deck joints (need repair). Drains or scuppers need cleaning.
6	**Satisfactory condition** – Medium scaling (¼" to ½" in depth). Excessive number of open cracks in deck (5 ft intervals or less). Extensive deterioration of the curbs, sidewalks, parapets, railing or deck joints (requires replacing deteriorated elements).
5	**Fair condition** – Heavy scaling (½" to 1" in depth). Excessive cracking and up to 5% of the deck area is spalled; 20 – 40% is water saturated and/or deteriorated. Disintegrating of deck edges or around scuppers. Considerable leaching through deck. Some partial depth failures, i.e. rebar exposed (repairs needed).
4	**Poor condition** – More than 50 % of the deck area is water saturated and/or deteriorated. Leaching throughout deck. Substantial partial depth failures (replace deck soon).
3	**Serious condition** – More than 60% of the deck area is water saturated and/or deteriorated. Use this rating if severe or critical signs of structural distress are visible and the deck is integral with the superstructure. A full depth failure or extensive partial depth failures (repair or load post immediately).
2	**Critical condition** – Some full depth failures in the deck (close the bridge until the deck is repaired or holes covered).
1	**"Imminent" failure condition** – Substantial full depth failures in the deck (close the bridge until deck is repaired or replaced).
0	**Failed condition** – Extensive full depth failures in the deck (close bridge until the deck is replaced).

Table 57 Bridge Inspection Sheet

ที่	Bridge Name	Deck		Cross beam		Pier		Others	
		LT	RT	LT	RT	LT	RT	LT	RT
1	สะพานข้ามคลองเตย	4	6	8	8	9	9	5	5
2	สะพานข้ามคลองบางอ้อ	4	6	8	6	9	9	6	5
3	สะพานข้ามคลองสะพานยาว	4	5	8	6	9	9	3	5
4	สะพานข้ามคลองมอญ	4	6	6	6	9	9	5	5
5	สะพานข้ามคลองเตาอิฐ	4	4	6	6	9	9	5	5
6	สะพานข้ามคลองบางรัก	5	5	8	8	9	9	5	5
7	สะพานข้ามคลองบางพระครู	4	6	6	6	9	9	3	4
8	สะพานข้ามคลองบางพลัด	6	4	4	5	6	5	2	2
9	สะพานข้ามคลองบางพลู	7	6	6	6	9	9	3	4
10	สะพานข้ามคลองบางยี่ขัน	4	4	4	4	3	8	4	4
11	สะพานข้ามคลองมอญ 2	3	3	3	3	3	4	3	3
12	สะพานข้ามคลองบางขุนนนท์	4		2		3		2	
13	สะพานข้ามคลองวัดเจ้าอาม	5		3		4		3	
14	สะพานข้ามคลองชักพระ	3		4		3		3	
15	สะพานข้ามคลองข้างวัดแก้ว	6		6		3		3	
16	สะพานข้ามคลองมอญ 3	4		6		4		3	

According to the BMA's criteria, the maintenance work has to be implemented for bridges with an NBI value of less than 5, BMA diagnoses the bridges with an NBI value of more than 5 as a pass. The diagnostic results are summarized in drawings and saved in the database.

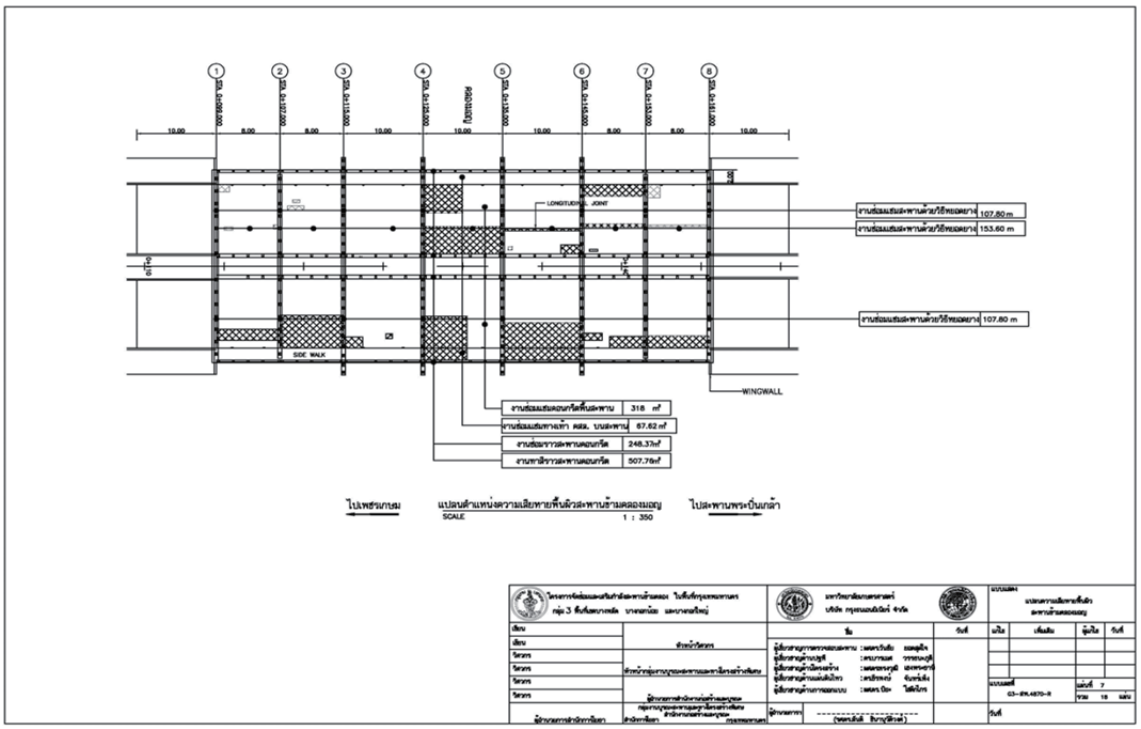
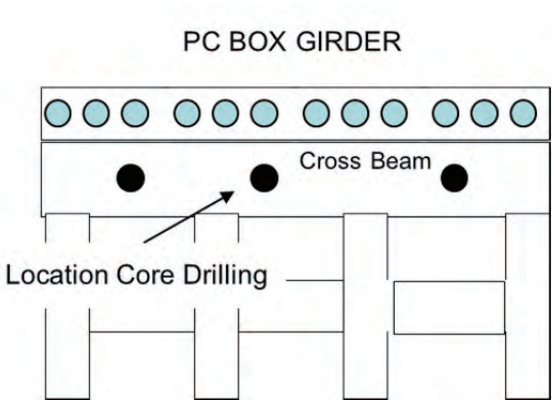


Figure 76 Diagnosis Record of Bridge

2) Material Testing

The concrete core sample is taken at the site for the compressive test to understand the condition of the concrete material, and BMA diagnoses the compressive strength of more than 210 kgf/cm^2 as a pass.



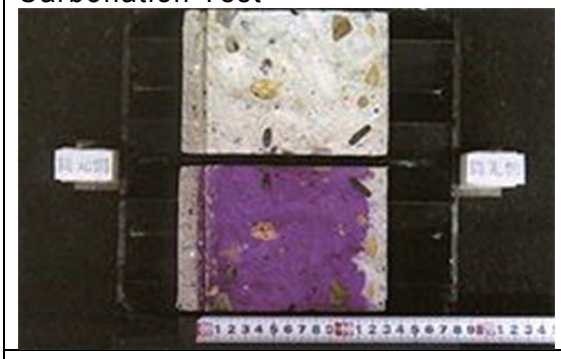
In addition, BMA measures the concrete compressive strength at the site using the site survey instruments without taking a core sample.

Windsor Probe Test

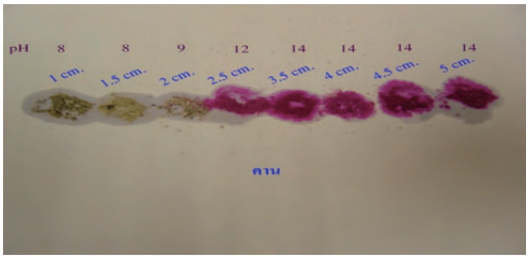
Rebound Hammer Test

Steel Tensile Strength Test

Carbonation Test

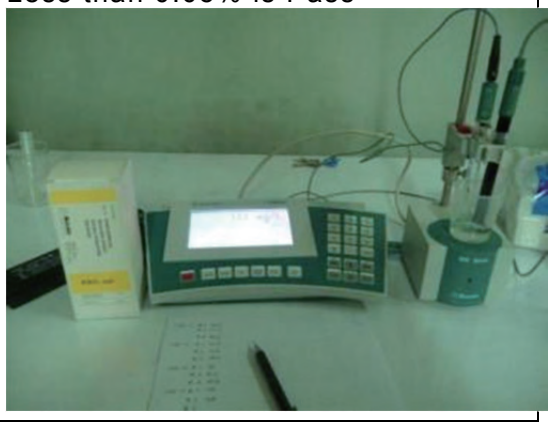


Carbonation Test at Site

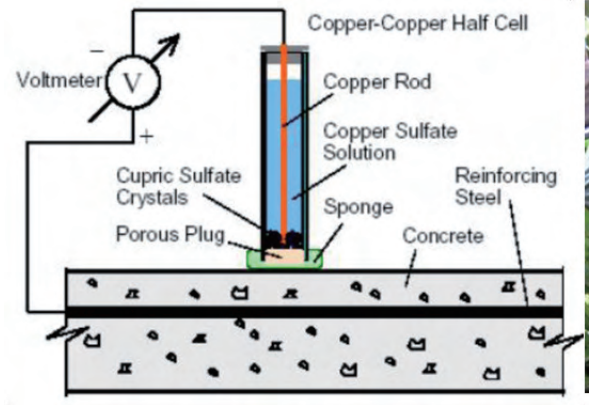


Chloride Test

Less than 0.05% is Pass



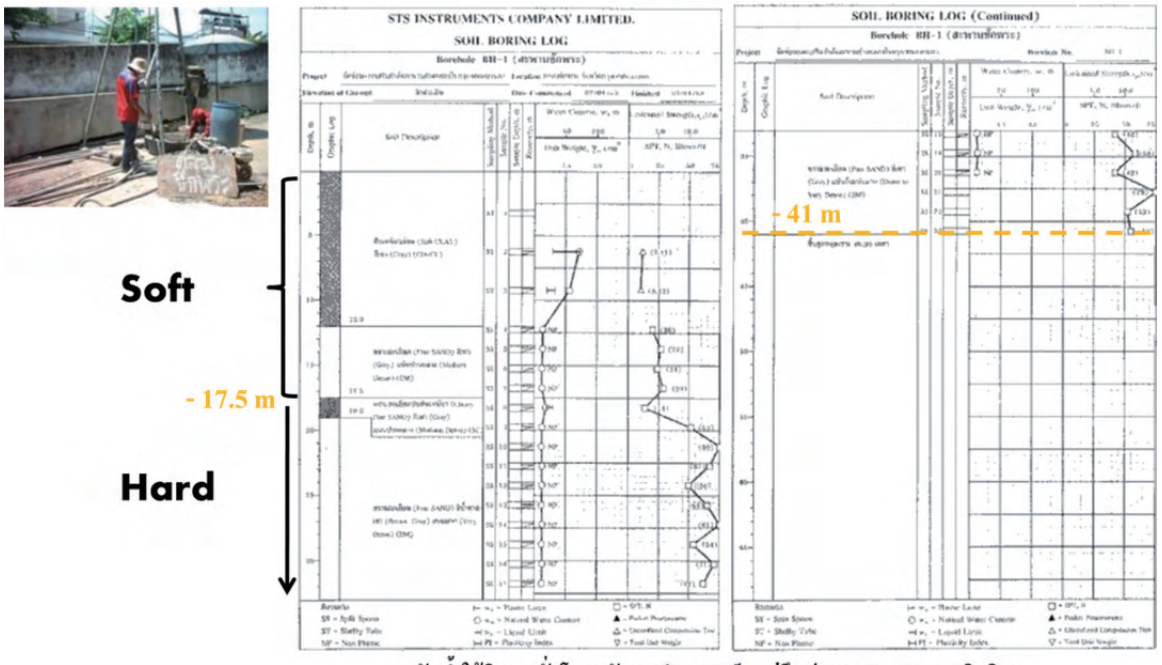
Half-cell Potential Test



3) Foundation Investigation

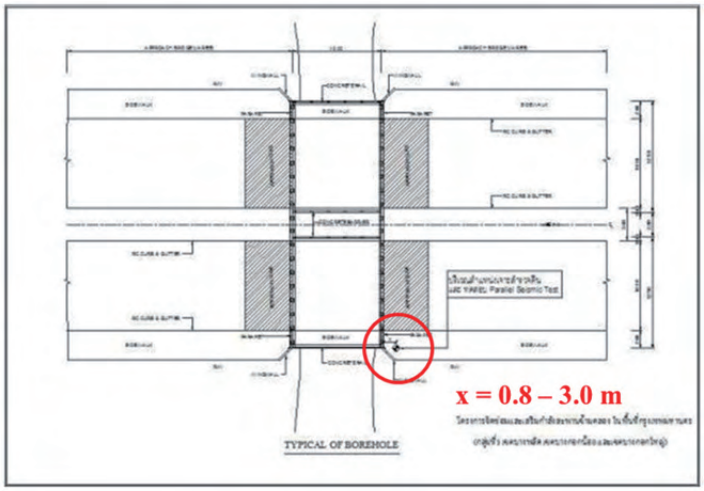
Geological survey is carried out by boring survey and by using various measurement instruments to understand the condition of the concrete foundations.

Boring Survey



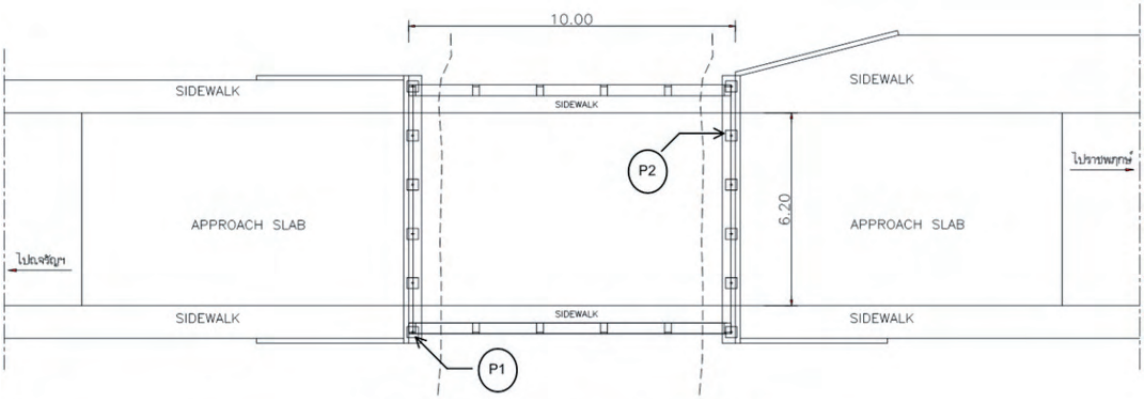
ระดับน้ำใต้ดิน 24 ชั่วโมงหลังจากสำรวจเสร็จ อยู่ลึกประมาณ 1.0 m จากผิวดิน

Parallel Seismic Test



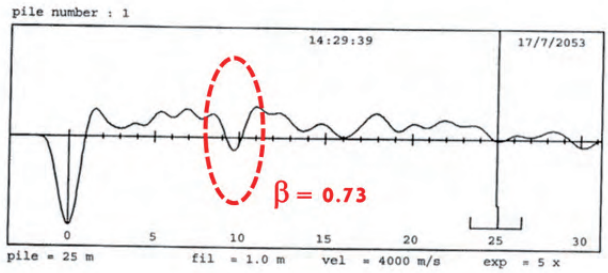
Testing Location

Side Echo Test for Concrete Piles



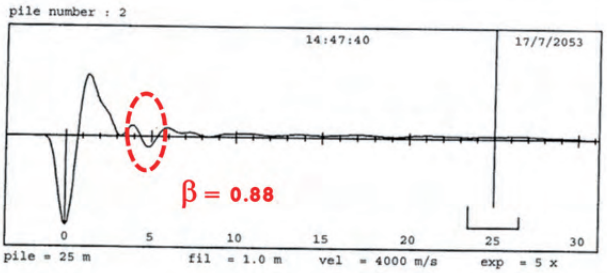
Side Echo Test Result

Pile P1 damages at 9.7 m

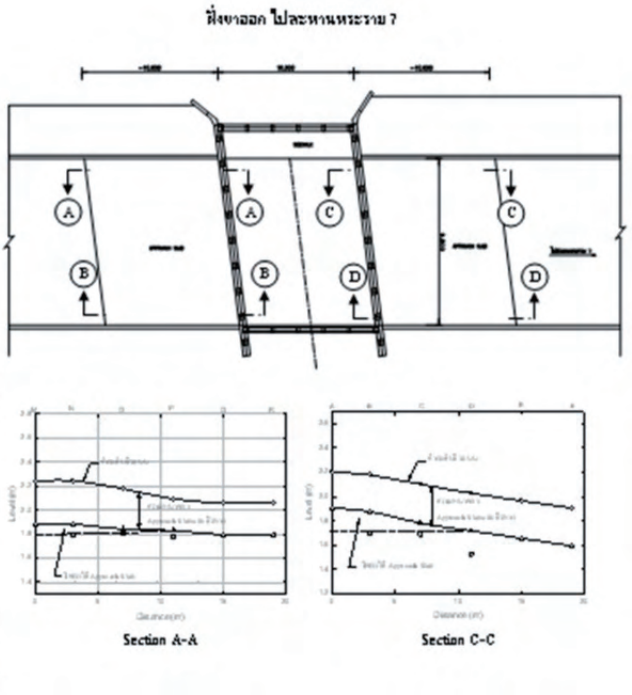


Pile P2 slightly damages at 5.0 m

β	Pile Condition
0.80 – 1.0	Slight Damage
0.60 – 0.80	Damage
< 0.60	Broken

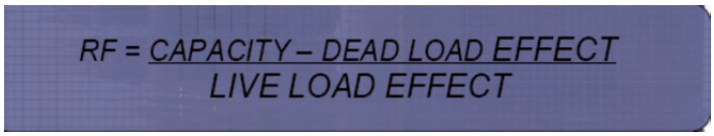


Approach Slab Investigation

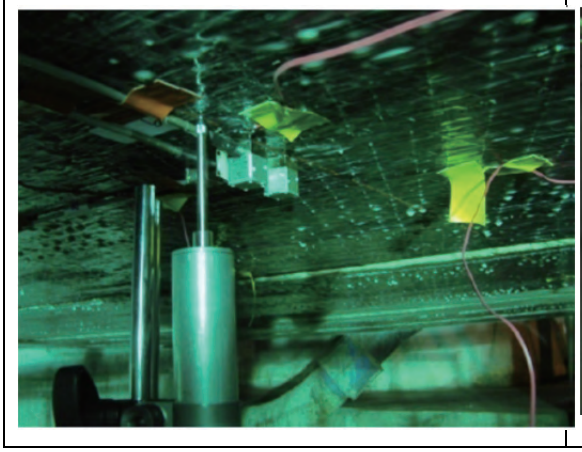


4) Evaluation (Check)

The bridge evaluation is executed in accordance with "Manual for Bridge Evaluation 2008", 1st Edition, with 2010 Interim Revisions by AASHTO modified from LRFR 2003, Load and Resistance Factor Rating. Rating factor is used to evaluate the allowable load weight and is calculated using the equation shown below.



The photos of loading test conducted are shown.

Loading weight	Loading weight
	
Measuring the deflection of concrete slab	Monitoring and collection of data
	

The rating results are summarized in the sheet.

ลำดับที่	แบบเลขที่	ชื่อสะพาน	SUPER STRUCTURE									
			CONDITION RATING		RATING FACTOR (MOMENT)				RATING FACTOR (SHEAR)			
					inventory		operating		inventory		operating	
			LT	RT	LT	RT	LT	RT	LT	RT	LT	RT
1	สพ.4860	สะพานข้างคลองเตย	4	6	0.78	1.02	1.01	1.32	0.94	1.19	1.22	1.54
2	สพ.4861	สะพานข้ามคลองบางอ้อ	4	6	0.78	1.02	1.01	1.32	0.94	1.19	1.22	1.54
3	สพ.4862	สะพานข้ามคลองสะพานยาว	4	5	0.78	0.94	1.01	1.22	0.94	1.10	1.22	1.43
4	สพ.4863	สะพานข้ามคลองมอญ1	4	6	0.78	1.02	1.01	1.32	0.94	1.19	1.22	1.54
5	สพ.4864	สะพานข้ามคลองเตาอิฐ	4	4	0.78	0.78	1.01	1.01	0.94	0.94	1.22	1.22
6	สพ.4865	สะพานข้ามคลองบางรัก	5	5	0.94	0.94	1.22	1.22	1.10	1.10	1.43	1.43
7	สพ.4866	สะพานข้ามคลองบางพระครู	4	6	0.78	1.02	1.01	1.32	0.94	1.19	1.22	1.54
8	สพ.4867	สะพานข้ามคลองบางพลัด	6	4	0.91	0.73	1.18	0.95	1.09	0.90	1.42	1.16
9	สพ.4868	สะพานข้ามคลองบางพลู	7	6	1.02	1.02	1.33	1.33	1.19	1.19	1.54	1.54
10	สพ.4869	สะพานข้ามคลองบางยี่ขัน	4	4	0.75	0.75	0.97	0.97	0.90	0.90	1.17	1.17
11	สพ.4870	สะพานข้ามคลองมอญ2(span 8m.)	3	3	1.29	1.29	1.67	1.67	1.06	1.06	1.37	1.37
		สะพานข้ามคลองมอญ2(span 10m.)			0.69	0.69	0.90	0.90	0.85	0.85	1.10	1.10
12	สพ.4871	สะพานข้ามคลองบางขุนนนท์(span 6m.)	4		0.74		0.96		1.59		2.06	
		สะพานข้ามคลองบางขุนนนท์(span 8m.)			0.95		1.23		1.27		1.64	
13	สพ.4872	สะพานข้ามคลองวัดเจ้าอาม plank(span 10m.)	5		0.89		1.16		1.56		2.03	
14	สพ.4873	สะพานข้ามคลองชักพระ (SECTION 2-2)	3		0.63		0.81		0.59		0.76	
		สะพานข้ามคลองชักพระ (SECTION 4-4)			0.47		0.61		0.82		1.06	
		สะพานข้ามคลองชักพระ (SECTION 5-5)			0.68		0.88		0.57		0.73	
		สะพานข้ามคลองชักพระ (ช่วงกลางสะพาน)			0.68		0.88		0.57		0.73	
		สะพานข้ามคลองชักพระ (ช่วงพื้นยื่น)			1.26		1.63		0.72		0.94	
15	สพ.4874	สะพานข้ามคลองข้างวัดแก้ว plank (span 10m.)	6		0.57		0.74		1.41		1.83	
16	สพ.4875	สะพานข้ามคลองมอญ3 plank (span10m.)	4		0.87		1.12		1.16		1.50	
		สะพานข้ามคลองมอญ3 plank (span12m.)			1.01		1.30		1.01		1.31	
		สะพานข้ามคลองมอญ3 slab type (span 6.5m.)			2.16		2.80		1.45		1.88	

Figure 77 Inspection Data of Super-structure

5) Repairing

The two upper photos show that the damaged parts being repaired by applying concrete or mortar after the damaged concrete has been removed, and the two lower photos show a concrete slab being reconstructed after the damaged part has been demolished.

Removal of damaged concrete and cleaning of reinforcing steel

Repair with mortar

Demolishing the damaged concrete slab

Reconstructing the concrete slab

6) Reinforcemnet

CFRP60 is one method being used for reinforcement of bridges.

NBI test is executed after the completion of applying CFRP to the damaged bridge to confirm the improvement. The inspection sheet on the next page shows that the damaged parts shown in yellow had been improved to satisfactory levels shown in blue.

[60] CFRP (Carbon Fiber Reinforced Plastic) is a very strong, light and expensive composite material or fiber-reinforced plastic. Similar to glass-reinforced plastic (known as fibre glass), the commonly used name of the composite material is taken from that of its reinforcing fibers (carbon fiber).

สรุป RATING FACTOR (SUPER STRUCTURE)

ลำดับที่	แบบแรกที่	ชื่อสะพาน	SUPER STRUCTURE							
			BEFORE STRENGTHENING				AFTER STRENGTHENING			
			RATING FACTOR (MOMENT)		RATING FACTOR (SHEAR)		RATING FACTOR (MOMENT)		RATING FACTOR (SHEAR)	
			LT	RT	LT	RT	LT	RT	LT	RT
1	สพ.4860	สะพานข้ามคลองเตย	0.78	1.02	0.94	1.19	1.19	1.02	1.25	1.19
2	สพ.4861	สะพานข้ามคลองบางซื่อ	0.78	1.02	0.94	1.19	1.19	1.02	1.25	1.19
3	สพ.4862	สะพานข้ามคลองสะพานยาว	0.78	0.94	0.94	1.10	1.19	1.19	1.25	1.10
4	สพ.4863	สะพานข้ามคลองมอญ1	0.78	1.02	0.94	1.19	1.19	1.02	1.25	1.19
5	สพ.4864	สะพานข้ามคลองสาธุ	0.78	0.78	0.94	0.94	1.19	1.19	1.25	1.25
6	สพ.4865	สะพานข้ามคลองบางรัก	0.94	0.94	1.10	1.10	1.19	1.19	1.10	1.10
7	สพ.4866	สะพานข้ามคลองบางพระครู	0.78	1.02	0.94	1.19	1.19	1.02	1.25	1.19
8	สพ.4867	สะพานข้ามคลองบางหลัด	0.91	0.73	1.09	0.90	1.15	1.15	1.09	1.22
9	สพ.4868	สะพานข้ามคลองบางพลู	1.02	1.02	1.19	1.19	1.02	1.02	1.19	1.19
10	สพ.4869	สะพานข้ามคลองบางยี่รัน	0.75	0.75	0.90	0.90	1.14	1.14	1.25	1.25
11	สพ.4870	สะพานข้ามคลองมอญ2(span 6m.)	1.29	1.29	1.06	1.06	1.29	1.29	1.06	1.06
		สะพานข้ามคลองมอญ2(span 10m.)	0.69	0.69	0.85	0.85	1.12	1.12	1.25	1.25
12	สพ.4871	สะพานข้ามคลองบางขุนนนท์(span 6m.)	0.74		1.59		1.33		1.59	
		สะพานข้ามคลองบางขุนนนท์(span 8m.)	0.96		1.27		1.37		1.27	
13	สพ.4872	สะพานข้ามคลองวัดเจ้าอาม plank(span 10m.)	0.89		1.56		1.39		1.56	
14	สพ.4873	สะพานข้ามคลองชักพระ (SECTION 2-2)	0.11		0.15		1.25		1.29	
		สะพานข้ามคลองชักพระ (SECTION 4-4)	0.47		0.82		1.27		1.24	
		สะพานข้ามคลองชักพระ (SECTION 5-5)	0.68		0.57		1.27		1.20	
		สะพานข้ามคลองชักพระ (ช่วงกลางสะพาน)	0.68		0.57		1.27		1.20	
		สะพานข้ามคลองชักพระ (ช่วงพื้นยื่น)	0.81		0.78		1.15		1.26	
15	สพ.4874	สะพานข้ามคลองร้างวัดแก้ว plank (span 10m.)	0.57		1.41		1.21		1.41	
16	สพ.4875	สะพานข้ามคลองมอญ3 plank (span10m.)	0.87		1.16		1.44		1.16	
		สะพานข้ามคลองมอญ3 plank (span12m.)	1.01		1.01		1.01		1.01	
		สะพานข้ามคลองมอญ3 slab type (span 6.5m.)	2.16		1.45		2.16		1.45	

Figure 78 Inspection Data of Super Structure Before and After Repair

(4) Database

Although there is no database for pavements, the database for bridges is being used extensively. In addition, tender documents have been prepared and have gained budgetary approval for the development of an integrated maintenance management system that covers both pavement and bridges. It will be contracted out in September 2014.

(5) Evaluation

A corrective maintenance system whereby repairs are only conducted after complaints are received from the public, is used for pavement maintenance, while the inspection and maintenance of bridges is implemented in a detailed and scientific manner, and the repair data are properly stored into the database so that the engineers in the office are able to diagnose the damage.

Engineers design the proper repairs by adopting new technologies based on the site survey data as preventive maintenance. As for the PDCA at the practical maintenance level, it is being implemented.

(6) Assessment of Present Condition of Asset Management and Issues

As for the asset management in terms of engineering, it is assessed to be well organized, although the Bangkok metropolitan area is a difficult area due to high population density, lively commercial activities, very congested traffic condition, etc. However, the current condition remains in a state of corrective maintenance with a lack of an economic or a long-term perspective because there are many things to be immediately dealt with. To strengthen its infrastructure management capacity, BMA should strengthen the cross cutting functions of its internal organizations.

4.5 Water Supply Sector

4.5.1 Overview of the Sector

Water supply service in Thailand is covered by Metropolitan Waterworks Authority (MWA) and Provincial Waterworks Authority (PWA). The service area of MWA is Bangkok Metropolitan and two provinces (Nonthaburi and Samuthprakarn) and that of PWA is the remaining provinces.

4.5.2 Metropolitan Waterworks Authority (MWA)

(1) Overview

1) Service area

The service area of MWA is the Bangkok Metropolitan and Nonthaburi and Samuthprakarn provinces.

Figure 79 Service Area of MWA

Raw water is abstracted from the Chao Phraya River and the Mae Klong Dam, and water is purified at four water purification facilities before being distributed throughout 18 water supply areas.

2) Infrastructure facilities

MWA has two raw water sources, four water purification facilities, and several kinds of pipes. Pipes are water conduits connecting raw water sources and water purification facilities, water pipes connecting water purification facilities and distribution reservoirs, main distribution pipelines from distribution reservoirs, distribution pipes coming off the main distribution pipeline, and feeder pipes connecting distribution pipes and consumers. Moreover, there are 43 pumping stations throughout the service area to increase water pressure and flow volume.

The length of the main distribution pipelines (500 - 1,800mm) is about 1,650km. Those pipelines are mainly steel pipes and standard cast-iron pipes. The distribution pipes (100 - 400mm) are 28,800km, 94% of the total pipe length, and 84% of the distribution pipe is poly

vinyl chloride (PVC) pipes (legal service life: 35 years, about 24,100km in 2013) and 14% is asbestos pipes (legal service life: 25 years, about 3,920km in 2013).

The length of PVC pipes is notably increasing because PVC pipes are used when existing asbestos pipes should be replaced and new pipes are installed. Currently MWA is extending its service area and installing new pipelines by 1,000km per year on average.

Table 58 Trend of Length of Distribution Pipes

Year	Iron pipe	Cast iron pipe	Asbestos pipe	PVC pipe	Galvanized iron pipe	High density polyethylene pipe	Total length
2009	301.550	22.412	4,829.269	18,932.323	268.521	45.958	24,400.033
2010	322.566	17.473	4,511.464	20,497.336	273.985	45.459	25,668.283
2011	351.610	16.817	4,251.797	21,980.165	280.624	45.728	26,926.210
2012	380.933	15.367	4,033.147	23,184.669	281.294	56.599	27,952.009
2013	399.881	15.330	3,920.051	24,136.508	280.166	59.555	28,811.491

Source: MWA

In Japan, ductile cast-iron pipes are widely used because of its durability, corrosion resistance, and adaptability for ground deformation by earthquakes. For small-bore pipelines, PVC pipes and recently high density polyethylene pipes are commonly used.

In Bangkok, ductile cast-iron-pipes are used only for about 3 km of main distribution pipeline at present. Currently MWA is planning to lay ductile cast-iron pipes (300 - 400mm) under intersections and sidewalks on a trial basis in order to evaluate applicability (cost, constructability, condition, and durability) of ductile cast-iron-pipes.

Land in Bangkok is flat, and in some areas water head is too low as 2 to 6m to supply water. Therefore there are pumping stations scattered around to acquire sufficient water pressure. In case of technical hitches, individual pumps are repaired or maintained by replacing parts. Some of the pumps have been used for over 40 years.

3) Organizations

MWA's water supply area consists of four Regions and each Region has four to six distribution areas. There are 18 distribution areas and every distribution area has its own branch office. Each branch office takes care of operation and maintenance of facilities.

Table 59 List of Regions and Branch Offices

Region 1	Region 2	Region 3	Region 4
Sukhumvit	Phayathai	Nonthaburi	Bangkok Noi
Pra Khanong	Tungmahamek	Prachachuen	Taksin
Samutprakarn	Mansi	Bangkhen	Suksawad
Suvarnabhumi	Ladprao	Min Buri	Phasi Charoen
			Bang Bua Thong
			Mahasawad

4) Financial condition

Revenue of MWA is 18.6 billion baht (1 billion baht increase from the previous year) and operating expense is 12.2 billion baht (0.3 billion baht increase from the previous year), in which maintenance cost is 660 million baht and depreciation and amortization is 4.4 billion baht. As a result, sales profit is 64 billion baht (0.67 billion baht increase from the previous year), and net profit is 7 billion baht (1.2 billion baht increased from the previous year) and net profit margin ratio is 38%. The half of the net profit is paid to the Ministry of Finance and the rest is stored retained earnings[61].

Table 60 MWA's Statement of Income

Unit : Mill baht

	2013		2012		Increase in 2013
Operating revenues					
Water sales	17,547	94%	16,777	95%	770
Other operating income	1,056	6%	828	5%	228
Total operating revenues	18,603	100%	17,605	100%	998
Operating expenses					
Raw materials and consumables used	2,555	14%	2,364	13%	191
Maintenance expenses	663	4%	557	3%	106
Depreciation and amortization expenses	4,411	24%	4,665	26%	-254
Other operating expenses	4,614	0%	1,117	0%	3,497
Total operating expenses	12,243	66%	11,919	68%	324
Profit from operating	6,359	34%	5,686	32%	673
Total Other revenues and expenses	732	4%	272	2%	460
Profit before finance cost	7,092	38%	5,957	34%	1,135
Finance costs	-83	0%	-166	-1%	83
Profit for the year	7,009	38%	5,792	33%	1,217
Payment to Ministry of Finance	3,492	50%	2,919	50%	573
Increse in retained earnings	3,517	50%	2,873	50%	644

Source : MWA Annual Report, 2013

Detailed maintenance expenses are shown in Table 61 Operating costs in the following table do not include MWA's labor costs involved in waterworks maintenance. Since 2013, operating costs including outsourcing costs and material costs for maintenance have been increasing.

Table 61 Operating Costs for Maintenance

Unit : Mill baht

	2013	2012
Contract out inspection and improvement of distribution valve	26.83	18.75
Contract out leakage pipes survey and repair	298.39	216.57
Repair and maintenance expenses	176.13	177.96
Pipe and equipment for repair and maintenance	161.63	143.72
Total	662.98	557.00

Source : MWA Annual Report, 2013

[61] Payments to the Ministry of Finance is decided as 45% of the net income. But it is adjusted during the year.

As of September 2013, MWA possesses 60.6 billion baht in assets, in which as high as 85% is physical fixed assets of about 51.8 billion baht. On the other hand, total liabilities amount to 11.2 billion baht and total equity is 49.5 billion baht (3.8 billion baht increase from the previous year) which is 82% of total assets. Retained earnings are 36.1 billion baht which is 60% of total assets. MWA has accumulated retained earnings well.

Table 62 MWA's Balance Sheet

Unit : Mill baht

	2013		2012	
ASSETS				
Cash and cash equivalents	5,120	8%	1,443	3%
Current investments	1,187	2%	1,950	3%
Other current assets	1,466	3%	1,625	3%
Total current assets	7,773	13%	5,018	9%
Non-current assets	0	0	0	0
Property, plant and equipment	44,556	73%	44,921	79%
Works under construction	7,257	12%	5,380	9%
Other non current assets	1,050	2%	1,455	3%
Total non-current assets	52,862	87%	51,756	91%
Total assets	60,634	100%	56,774	100%
LIABILITIES AND EQUITY				
Liabilities				
Current liabilities				
Current portion of long term loans	160	0%	708	1%
Other current liabilities	6,181	10%	3,829	7%
Total current liabilities	6,341	10%	4,537	8%
Non-current liabilities				
Long term loans	1,330	2%	3,016	5%
Other non current liabilities	3,490	6%	3,594	7%
Total non-current liabilities	4,820	8%	6,610	12%
Total liabilities	11,161	18%	11,147	20%
Equity				
Capital	13,339	22%	13,017	23%
Unappropriated retained earnings	36,124	60%	32,605	57%
Total equity	49,473	82%	45,627	80%
Total liabilities and equity	60,634	100%	56,774	100%

Source : MWA Annual Report, 2013

Breakdown of physical fixed assets, which accounts for 73% of the total asset shows that approximately 70% of the physical fixed assets, or 30.4 billion baht[62] is comprised of pipelines.

[62] Property, plant, and equipment under construction are not included.

Table 63 Physical Fixed Assets

Unit : Mill baht

	Costs	Accumulated depreciation /impairment	Net book value	Depreciation period (years)
Land	4,284	0	4,284	30
Building and improvements	16,962	10,192	6,770	30
Machineries and equipments	9,579	7,370	2,209	5 , 10 , 20, 25
Pipes	72,073	41,659	30,414	10 , 25 , 35
Meters	3,412	2,832	580	5 , 8
Office equipments	1,102	883	220	5
Vehicles and transport	321	241	80	5 , 8
	107,734	63,179	44,556	

Source : MWA Annual Report, 2013

By analyzing MWA's 2013 financial indices, earning power is high as net profit ratio is 38%. Savings for investment for replacement of infrastructure facilities[63] is not high as cash flow from investing activities and cash and cash equivalent is 15% of accumulated depreciation and amortization expenses due to high fixed asset ratio. Therefore, it is not considered to be a serious problem. The level of deterioration does not seem to be serious although 59% of costs of fixed asset are already depreciated. This is mainly because depreciation year is set shorter than the service life of pipes. .

Table 64 Major Financial Index

Assessment item	Index	2013
Earning power	Net profit ratio	38%
Savings for investment for replacement	Cash to be used for investment for replacement / accumulated depreciation and amortization expenses	15%
Level of deterioration	Accumulated depreciation / cost of fixed asset	59%

Overall, MWA has strong earning power and no serious problem is found in savings for investment for replacement of infrastructure facilities or level of deterioration.

(2) Maintenance and Repair of Pipelines

1) Plan

Replacement plan

MWA is struggling to lower the water leakage ratio. Since the majority of pipelines are distribution pipes made of asbestos pipes and PVC pipes, MWA prioritizes replacing these two types.

[63] Cash to be used for investment for replacement / accumulated depreciation and amortization expenses, Cash to be used for investment for replacement = cash flow from investing activities + cash and cash equivalents + current investment

Leakage control and pipeline replacement plan developed before 2008 was to replace 4% of existing pipelines every year because the average life cycle of a pipeline is 25 years and by replacing 4% a year will enable the replacement of all pipelines in 25 years.

Yet the plan means that MWA may replace sound pipelines unnecessarily and that it is difficult to grasp which pipelines leak most frequently. In order to cope with this issue, in 2008 MWA installed District Meter Area (DMA) for maintenance of distribution pipes. DMA divides distribution area into smaller areas and allows MWA to grasp detailed leakage conditions. Then MWA can prioritize replacement of pipelines which leak frequently and as it resulted in decreasing the length of pipelines that need replacing.

Criteria used for deciding priorities for replacement of pipelines are the five items below.

1. Age of pipelines
2. Frequency of water leaks
3. Water leakage ratio
4. Depth of pipeline burial
5. Pipeline type

Using GIS, MWA was able to ascertain that there is approximately 1,000 km of asbestos pipes which were laid more than 20 years ago. In addition, asbestos piping that was laid more than 20 years ago will increase 150 to 300 km every year. Therefore, MWA has amended its replacement plan to replace 300 km of asbestos piper per year from 2008 to 2014 by prioritizing replacement based on the criteria. In 2015 or later, MWA will develop pipeline replacement plan by prioritizing pipelines to be replaced and implement the plan.

Budget plan

In MWA all 18 branch offices develop their budget request and the headquarters assemble them into the total budget plan. Each branch office prepares pipeline replacement plan based on the criteria and budget request accordingly. MWA needs the permission from BMA to excavate roads for laying pipes. Since the permission is good for one year, MWA prepares the budget on a yearly basis and MWA sometimes fails to execute the works in the following year due to BMA's disapproval.

2) Implementation (Do)

MWA focuses on repair and replacement of the following four types of pipes based upon repair history.

Table 65 Water Leakage Causes and Repair Works

Pipe material	Purpose	Major causes for water leakage	Pipe condition
Asbestos	Distribution trunk and pipe	・Misalignment due to uneven land subsidence ・ Degradation by aging	
PVC	Distribution pipe	・Misalignment due to uneven land subsidence	
Galvanized iron	Distribution pipe	・Corrosion by chlorine in water	
Polybutylene	Feed pipe	・Misalignment due to uneven land subsidence ・Degradation by aging	

3) Evaluation (Check)

Use of GIS

About 10 years ago, MWA introduced GIS for information management of pipeline facilities. In the past, they used 1/4000 maps that had minimal information such as location, material, and diameter of pipelines.

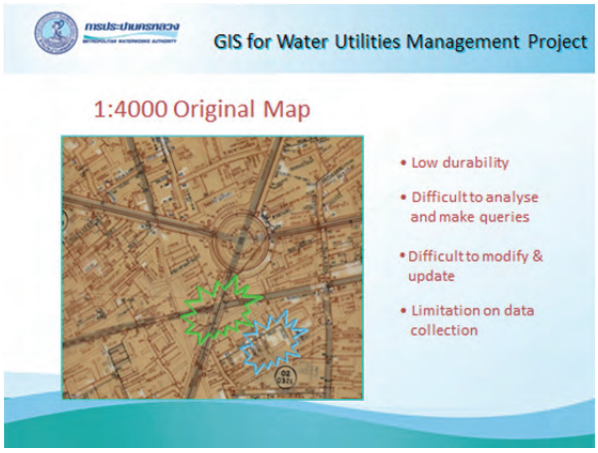


Figure 80 Previous Management Tool

Source: MWA

Since MWA installed its GIS, the GIS server there has been set up in a room exclusively for information management and updating of the GIS data. MWA utilizes the installed 1/1,000 topography data, pipeline location data and other attribute information such as users.

When updating the data, the as-built drawings (pipe layout, etc.) cooperated with vector data are scanned into GIS, and updated vector data for GIS are added.

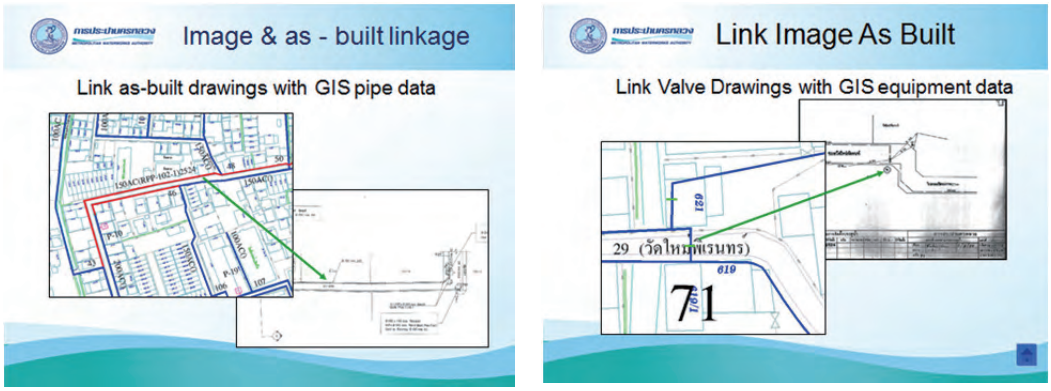


Figure 81 Linking Pipeline Facility Maps with As-built Drawings

Source: MWA

GIS information is accessible from the MWA headquarters, 18 branch offices in Bangkok and also from the call center. It is also accessible from mobile devices to browse information and to add information so that information related to water leakage and new meter connections are added in GIS on the spot. Furthermore, GIS is used to accumulate water usage data from water meters. This data is used to compute water usage by area for pipe network analyses, which is used as the base for selecting the diameter of pipes when replacing or installing new pipes.

Figure 82　GIS Usage in MWA

Use of SAP

Together with GIS, SAP is installed in every branch office, water purification facility, and pumping station. Pipeline information is updated always in branch offices and stored as a ledger.

4)　Review (Action)

Focus on pipe replacement plan is shifting from asbestos pipes to PVC pipes because the number of water leaks in asbestos pipes decreased from 2010 to 2013, on the other hand that in PVC is increasing. From 2014, replacement of 400km/year of PVC pipes is included in the pipe replacement plan and implemented.

Table 66 Number of Asbestos and PVC Pipe Water Leaks

Pipe type	Number of water leaks (number/100 km/month)		Remarks
	2010	2013	
Asbestos	10	4.7	Legal durable year: 25 years Number of water leaks has decreased.
PVC	2	2.3	Legal durable year: 35 years Number of water leaks is increasing.

As a consequence, pipeline replacement plan was reviewed and updated as follows.

Table 67 Change in Pipeline Replacement Plan

Before 2008	2009~2014	2015~
・ Pipeline replacement（80%） ・ Water leakage（20%）	・Asbestos pipes buried more than 20 years ago（80%） ・Water leakage（20%）	・Asbestos pipes buried more than 20 years ago ・PVC pipes buried more than 30 years ago ・Water leakage ・Replacement cost

Source: MWA

(3) Maintenance and Repair of Water Purification Plants and Pump Stations

1) Plan

There is no long-term replacement plan of pumping stations or water purification facilities. MWA, however, develops an annual replacement and repair plan, respectively, based on the condition of facilities and ages.

2) Implementation (Do)

Pumps are replaced when necessary. Water purification facilities are repaired to prolong their life by applying water-resistant coating in filter basins and replacing iron plates with stainless plates.

Figure 83 Before and After Repair of Filter Basin

3) Evaluation (Check)

At water purification facilities and pumping stations, engineers keep paper-based material and equipment ledgers, however, staff in headquarters cannot obtain real-time information. Although SAP is introduced, it is not utilized because operation and maintenance engineers lack skills to use SAP. Therefore, headquarters need to call to each facility to obtain necessary information, which is time consuming.

4) Review (Action)

At pumping stations, installation of small-scale pumps is planned to increase water pressure without increasing water leakage.

At the water purification facilities, taking repair history into account, MWA focuses on reduction of water leakage from raceway in the water purification plants. However, MWA cannot come with any measures without causing inconvenience to users by temporarily stopping water conveyance. Therefore, MWA is seeking for advisors to find a solution to this problem.

Figure 84 Water Leakage in Water Purification Facility

(4) Technical Cooperation by Japan

1) JICA's technical cooperation

JICA has been dealing with MWA such as technical cooperation and loan assistance (Project: 1st - 8th Bangkok Water Supply Improvement Project from 1979 to 2009). At the 8th Bangkok Water Supply Improvement Project, JICA implemented additional technical assistance from November 2010 to March 2013. The details of additional assistance were to share knowledge and experience of Japanese waterworks organizations in Osaka, Nagoya, and Tokyo. In addition, JICA conducted training in Japan and dispatched experts to Thailand to transfer facility management skills.

2) Technical cooperation with the Bureau of Waterworks Tokyo Metropolitan Government (BWTMG)

BWTMG implemented a series of cooperation and assistance in the 8th Bangkok Water Supply Improvement Project by 2012.
Upon ending of JICA's project, BWTMG and MWA signed new memorandum for human resource development and they have been working for exchanging staff program since 2013. Transportation and accommodation fees are paid by the dispatcher and costs for study tour and training are paid by the accepting organization.

3) Technical cooperation with Japanese private sector

Tokyo Suido Services Co., Ltd (TSS) and BWTMB are implementing technical assistance to MWA.

1. Field test for water leakage control in Bangkok (May 2011)

   Uncollectable water rate decreased from 28% to 3%.

2. Establishment of the joint venture TSS-TESCO Bangkok Co., LTD (Capital: JPY13 Million)

   TSS invested 49% and jointly started water supply business with TESCO in September 2012.

(5) Assessment of Current Asset Management Situation

MWA establishes maintenance system for infrastructure facilities; MWA manages conditions of pipelines and facilities using GIS, and implements necessary facility improvements based on MWA's analysis such as installing new distribution pipes to expand service areas, replacing asbestos pipes and PVC pipes, and conducting repair work against water leakages. Yet currently MWA is conducting corrective maintenance based on mid-term plans, not preventive maintenance and life extension based on long-term integrative plans with a far-sighted perspective on the condition of infrastructure facilities over decades.

MWA's problem regarding asset management is that they cannot forecast long-term operation and maintenance costs because environment is not improved enough to accumulate and analyze necessary data to develop long-term plans. Their challenges necessary to strengthen business sustainability are to forecast long-term demand for water, identify problems, and develop and implement long-term and integral asset management plans to cope with the problems.

4.5.3 Provincial Waterworks Authority (PWA)

(1) Overview

1) Service area

PWA manages all waterworks systems throughout Thailand except waterworks controlled by MWA in Bangkok metropolitan area (i.e. Bangkok, Nonthaburi, Samuthprakarn). Intended numbers of users are approximately 3.6 million connections (14.8 million people) which covers 16% of the whole of Thailand. This number is greater than MWA's users (approximately 2.1 million connections; 8.4 million people; 9% of the whole of Thailand).

2) Infrastructure facilities

The water supply business around Bangkok started in 1990s. To solve ground subsidence and groundwater contamination, the Thai government planned to inject private money and technology to build a water purification facility. Thai Tap Water Supply Co., Ltd. (TTW) was established and they built two water purification facilities in West Bangkok and North Bangkok. Currently TTW purifies and supplies 400,000 m3/day of clean water for West Bangkok (Nakon Patom & Samut Sakhon) and North Bangkok (Pathum Thani), which accounts for 1/3 of the total water supplied by PWA. Currently TTW own, operate and maintain these water purification facilities. PWA purchases purified clean water from TTW and supplies it to its service area. PWA is going to take over the water purification facility in the North in 2023 and that in the West in 2034.

3) Organizations

PWA has its headquarters in Bangkok, 10 domestic regional offices, and 233 branch offices in 233 branches (waterworks facilities). As shown on Table 55, branches are categorized into four groups based on the numbers of users.

Table 68 Number of Branches by Group

Groups	Numbers of users	Numbers of branches
1. Small Scale Water Utilities	Under 15,000	169
2. Medium Scale Water Utilities	15,001－40,000	41
3. Large Scale Water Utilities	40,001－80,000	14
4. Special Water Utilities	More than 80,001	9
Total		233

Source: PWA

PWA outsources operation and maintenance of large branches with over 50,000 users. Currently, 20 facilities are outsourced and PWA operates and maintains the rest.

As of May 2014, PWA has 7,730 employees, 987 in the headquarters in Bangkok and 6,743 in 10 regional offices and 233 branches.

Each regional office manages 20 to 25 branches. Each branch office reports to its regional office about the condition of waterworks facilities and each regional office reports to the PWA headquarters in Bangkok.

PWA is planning to increase two branches by Oct. 2014.

4) Financial Conditions

MWA yields total revenue of 21.1 billion baht (3 billion baht increase from the previous year). Total expense is 16.4 billion baht (1.5 billion baht increase from the previous year) and 0.9 billion baht was spent for maintenance and repair for mainly materials and outsourcing cost. As a result, net profit amounts to 40 billion baht (1.6 billion baht increase on the previous year) and net profit margin ratio is 19%.

Table 69 PWA's Statement of Income

Unit : Mill baht

Item	2012		2011	
REVENUES				
Income from water sales and services	19,488	92%	16,579	91%
Income from pipeline installation	1,686	8%	1,559	9%
TOTAL REVENUES	21,175	100%	18,138	100%
EXPENSES				
Operating and administrative expenses	15,040	71%	13,664	75%
Costs of pipeline installation	1,311	6%	1,209	7%
TOTAL EXPENSES	16,351	77%	14,873	82%
Finance costs	2,243	11%	1,903	10%
Profit for the year	4,029	19%	2,478	14%
Other comprehensive income (loss) - net	-1		-1	
Total comprehensive income for the years	4,028	19%	2,477	14%
Remittance to the Ministry of Finance	2,044	51%	1,197	48%
Increase in unappropriated retained earnings	1,984	49%	1,280	52%

Source: PWA Annual Report 2012

As of September 2012, PWA possesses 83.6 billion baht. Within total assets, physical fixed assets including under construction is 71.2 billion baht, which is as high as 85% of total asset. Total liabilities are 55 billion baht and total equity is 28.5 billion baht which is a 900 million baht increase from the previous year and it is 34% of total assets. Retained earnings are, however, still negative 500 million baht, and are not enough for future investment.

Table 70 PWA's Balance Sheet

Unit: Mill baht

Item	2012		2011	
ASSETS				
TOTAL CURRENT ASSETS	8,739	10%	8,578	11%
NON-CURRENT ASSETS				
Property, buildings and equipment	71,224	85%	67,979	84%
Other non-current assets	3,594		4,546	
TOTAL NON-CURRENT ASSETS	74,817	90%	72,526	89%
TOTAL ASSETS	83,556	100%	81,104	100%
LIABILITIES				
TOTAL CURRENT LIABILITIES	8,393	10%	7,642	9%
NON-CURRENT LIABILITIES				
Long-term loans from financial institutions - net	-		810	1%
PWA's bonds - net	10,200	12%	10,150	13%
Other non-current assets	36,443		34,906	
TOTAL NON-CURRENT LIABILITIES	46,643	56%	45,866	57%
TOTAL LIABILITIES	55,036	66%	53,508	66%
EQUITIES				
Total capital	33,124	40%	33,124	41%
Unappropriated retained earnings (loss)	-5,054	-6%	-5,980	-7%
TOTAL EQUITIES	28,520	34%	27,596	34%
TOTAL LIABILITIES AND EQUITIES	83,556	100%	81,104	100%

Source: PWA Annual Report 2012

Breakdown of physical fixed assets[64], which accounts for 76% of the total asset shows that approximately 78% of the physical fixed assets, or 49.7 billion baht is comprised of building and construction, whose depreciation year is 3-50 years.

Table 71 Physical Fixed Assets

Unit : Mill baht

	Cost price	Accumulated depreciation	Accumulated impairment	Net book value
Land	2,282	0	8	2,274
Building and construction	77,485	26,924	817	49,744
Equipment	11,374	7,445	38	3,892
Assets under Financial Lease	16,511	4,343	4,465	7,703
Total	107,652	38,711	5,328	63,614

Source : PWA Annual Report, 2012

By analyzing PWA's 2012 financial indices, earning power is not as high as MWA as net profit ratio is 19%. Savings for investment for replacement of infrastructure facilities[65] shows that savings is about one third of the accumulated depreciation expenses as cash flow from investing activities and cash and cash equivalent is 36% of accumulated depreciation and amortization expenses. The level of deterioration does not seem to be serious 37% of costs of fixed asset are already depreciated.

[64] Physical assets under construction are not included.
[65] Cash to be used for investment for replacement / accumulated depreciation and amortization expenses, Cash to be used for investment for replacement = cash flow from investing activities + cash and cash equivalents + current investment

Table 72 Major Financial Index

Assessment item	Index	2012
Earning power	Net profit ratio	19%
Savings for investment for replacement	Cash to be used for investment for replacement / accumulated depreciation and amortization expenses	36%
Level of deterioration	Accumulated depreciation / cost of fixed ass et	37%

The service area of PWA is widely spread with low density. PWA's service was once unprofitable, therefore, retained earnings are still negative. However, it improved recently and financial conditions are accordingly improving. In future when PWA extends service areas to isolated areas, the government intends to subsidize for their business so as not to negatively affect PWA's business performance.

(2) Maintenance and Repair of Facilities

1) Plan

As of now, although the average water leakage rate is about 28%, it is about 36 to 40% or higher for some branches. PWA therefore understands that measures to combat water leakages are an important issue and prioritize repair and replacement of pipelines. PWA plans to replace pipelines in accordance with the priority to reduce water leakage rate and expects to improve water supply service by preventing accidents caused by water leakage.

Currently PWA sets the following operational strategy.

Table 73 PWA's Business Strategy

Target	Strategy
1. Proper water source management	1-1. Secure quality of raw water 1-2. Introduce raw water quality monitoring system 1-3. Combine distribution areas for appropriate raw water usage
2. Environmentally friendly water purification system and correspondence to water demand	2-1. Facility improvement to meet water demand 2-2. Introduce SCADA for operation management 2-3. Introduce preventive maintenance method for improvement 2-4. Upgrade water purification for water quality improvement 2-5. Respond to environmental issues compliant to ISO14000. 2-6. Introduce new technology for efficient operation 2-7. Introduce business continuity management
3. User oriented facility operational system	3-1. Expand distribution areas 3-2. Technical support for local branches 3-3. Water leakage management 3-4. Install/replace new flowmeters and evaluate data
4. International standardized water management	4-1. Provide hydraulic information 4-2. Improve laboratory based upon ISO/IEC17025 4-3. Set water purification flow and water quality control

PWA intends to shift from corrective maintenance to preventive maintenance as for repair and replacement of pipelines and acquires budget for implementation. Currently, PWA is developing an implementation plan.

2) Implementation (Do)

Though each branch office is supposed to operate and maintain waterworks facilities in the branch, it is difficult to keep a standard quality of maintenance because topographical & natural conditions and level of skills of engineers are different by branches. PWA intends to use outsourcing more, however, it is not realized yet due to shortages in budget and human resource. At large branches, as is the case with MWA, PWA divides a water supply area into several District Management Areas (DMAs). By installing flowmeters at the boundary of every DMA, the flow volume is measured all of the time. If unusual flow is found, PWA assumes that there is a potential water leakage and they visit and check the site and repair pipelines.

In Rangsit branch nearby Bangkok metropolitan area, this system is introduced in 2012 and flow rate data of all 60 DMAs in the water supply area are uploaded on the web all the time and can be accessed anywhere and anytime. Therefore, staff can check what is happening at the site on the web even when he/she is out of office if the flow rate data shows anomalous value.

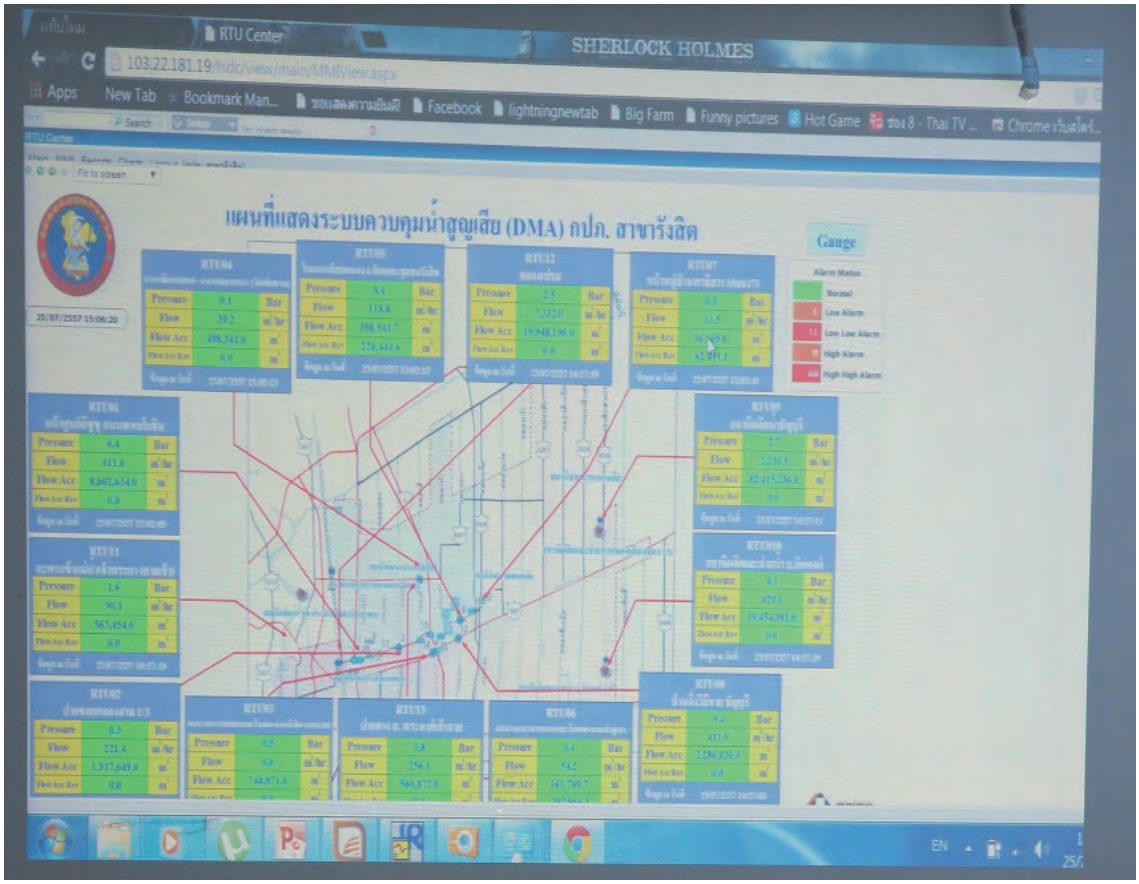


Figure 85 Flow Rate in Distribution Pipe

3) Evaluation (Check)

PWA uses GIS for information management of pipelines and GIS has been. Their GIS, which is different from that of BMA, MEA and MWA, is installed in all 233 branch offices and used for placing pipeline locations and detailed information on digital topography data.

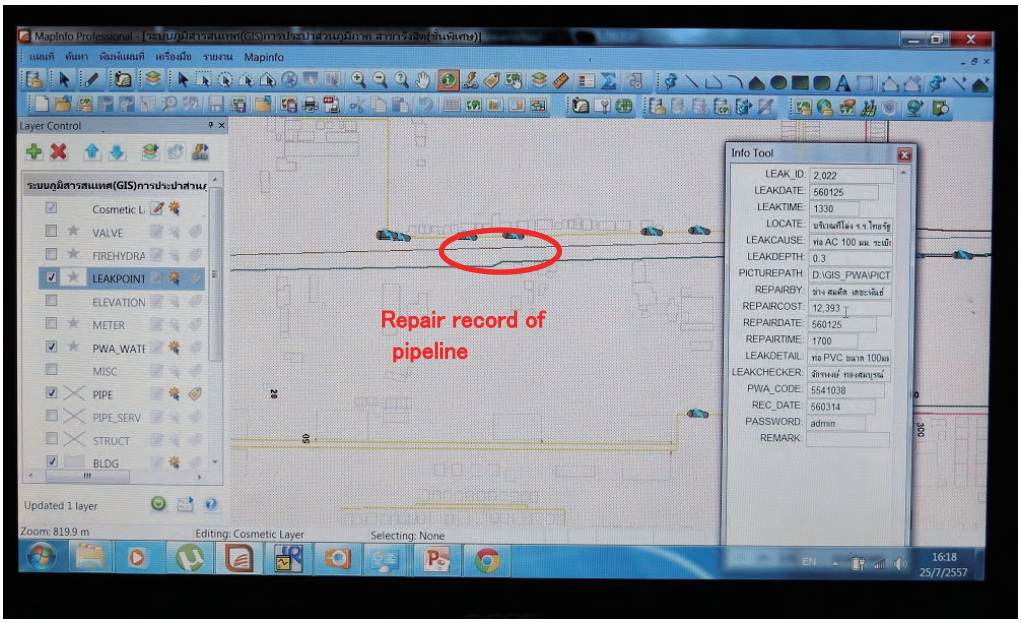


Figure 86 Repair History of Pipelines

At branches, the GIS is used to keep track of the water leakage and repair history. These records are useful to prioritize distribution pipes to be replaced and to supply water usage data for hydrologic accounting to plan future expansions.

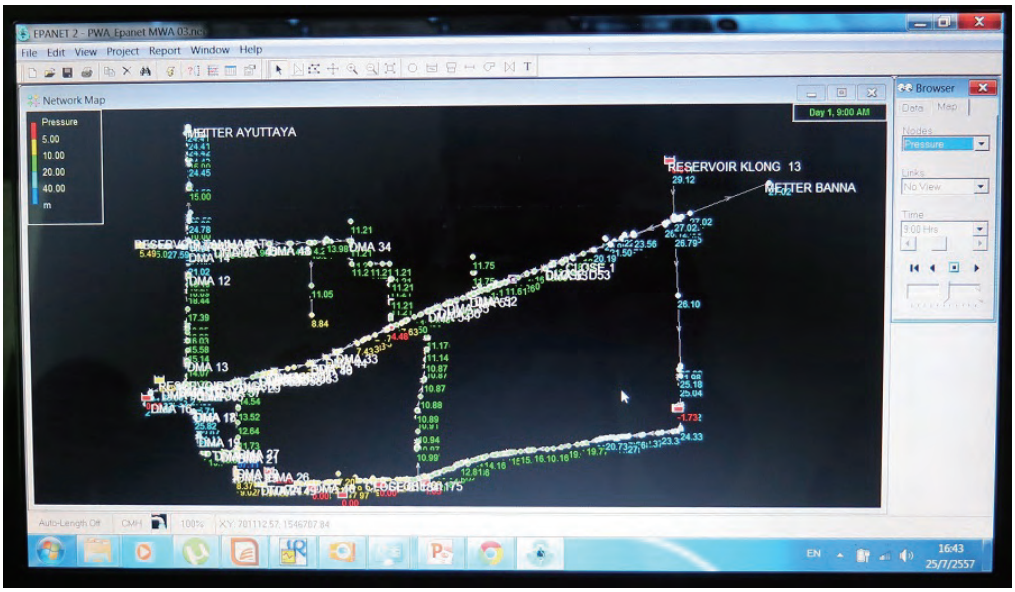


Figure 87 Hydrological Accounting (Rangsit Branch)

However some branch offices in remote locations do not always update pipeline information.

4) Review (Action)

Even in large branch offices, basic data such as repair and replacement of pipelines are recorded, but data on how pipes are buried and ground conditions are not collected. Therefore, PWA cannot analyze what condition is related to frequency of repair and utilize the analysis into prioritizing pipelines to be replaced.

(3) Technical Cooperation by Japan

1) JICA's Grass Roots Technical Cooperation

From April 2011 to March 2014, at Chonburi Thailand, Saitama Prefecture implemented grass roots technical cooperation about water treatment. They dispatched experts to Chonburi and accepted trainees in Japan from PWA. They improved management skills of filter pond and sedimentation pond, lowered manganese and enhanced water treatment skills.

Results are as follows.

1. Improvement of PWA's skills
   - Cleaning skills of filter ponds
   - Chlorine management skills
   - Sludge removal management skills
   - Acquisition of Japanese waterworks knowledge
2. Development of international understanding of Saitama Prefectural officials

After that, JICA and Saitama Prefecture Bureau extended technical assistance for capacity development of PWA in operation and maintenance of water purification plants for Chiang Mai and Nong Khai waterworks. The duration of project is 2.5 years (August 2013 – March 2016).

(4) Current Status and Challenges of Asset Management

PWA is already equipped with required software and hardware for operation and maintenance of facilities. They can analyze their own data and develop future operation and maintenance plan. Although their way of maintenance was on a corrective maintenance method basis, they also have the will to shift to a preventive maintenance method basis. However, because of large numbers of facilities, geographically scattered and difference in specifications of facilities by region, it is not easy to standardize operation and maintenance method. Since budget is limited, PWA does not have the choice but to prioritize densely populated areas near the metropolitan area the issue is how to improve the service quality in remote areas.

4.6 Sewerage Sector

4.6.1 Overview of the Sector

Sewerage works in Bangkok Metropolitan is under the Bangkok Metropolitan Administration (BMA)'s control and the remaining areas are covered by the Wastewater Management Authority (WMA).

4.6.2 Bangkok Metropolitan Administration (BMA) Drainage and Sewerage Department (DSD)

(1) Drainage and Sewerage System in Bangkok Metropolitan Area

DSD is responsible for construction and maintenance of drainage and sewerage system in Bangkok metropolitan area and for maintaining mainly the following facilities.

- Drainage and sewerage culverts: approximately 6,400 km
- Storm outfall pit: more than 1000 pits
- Sewage treatment plant: 7 plants
- River dike
- Drainage pump station

Combined sewer system is commonly used in Bangkok because sewer lines in Bangkok were originally constructed for stormwater drainage. Sewerage system is equipped with stormwater outfall pits, and during dry season, only sewage flows into combined sewer pipes and is conveyed to the sewage treatment plant for treatment. During rainy season, both stormwater and sewage water flow in combined sewer culverts and usually up to five times the amount of water compared to dry season is conveyed to sewage treatment plant. The excess water is discharged to waterways or rivers after getting rid of refuses through rainwater discharge pits. There are more than 1,000 stormwater discharge pits installed in Bangkok. However, for the areas without stormwater discharge pits, stormwater and sewage water are collected through combined sewer system and discharged to waterways or rivers.

In Bangkok, pollution concentration of wastewater is low because installation of septic tank is mandated. Furthermore, due to unidentified water flowing into the sewerage system such as backward water from canals or inflows of ground water, the quality of collected water in sewage treatment plants is about 42 mg/1 (BOD based, average of 2013) which is half to 1/3 that of Tokyo (146 mg/1, 2012, Bureau of Waterworks Tokyo Metropolitan Government). Taking this factor into account, low cost treatment systems are utilized.

The total wastewater generation amount in Bangkok is approximately 300 mill m^3/year and only approximately 100 mill m^3/year of wastewater is treated. The diameter of sewage pipes are generally from 0.3 meter to 5.0 meter, and the types of pipe used are mainly RC pipes and some PVC pipes, etc. There are some sewage pipes which have passed more than 30 years after being laid.

(2) Organization

As of 2013, DSD has 500 employees. There are 156 government officers, 282 permanent employees and 62 non-permanent employees.

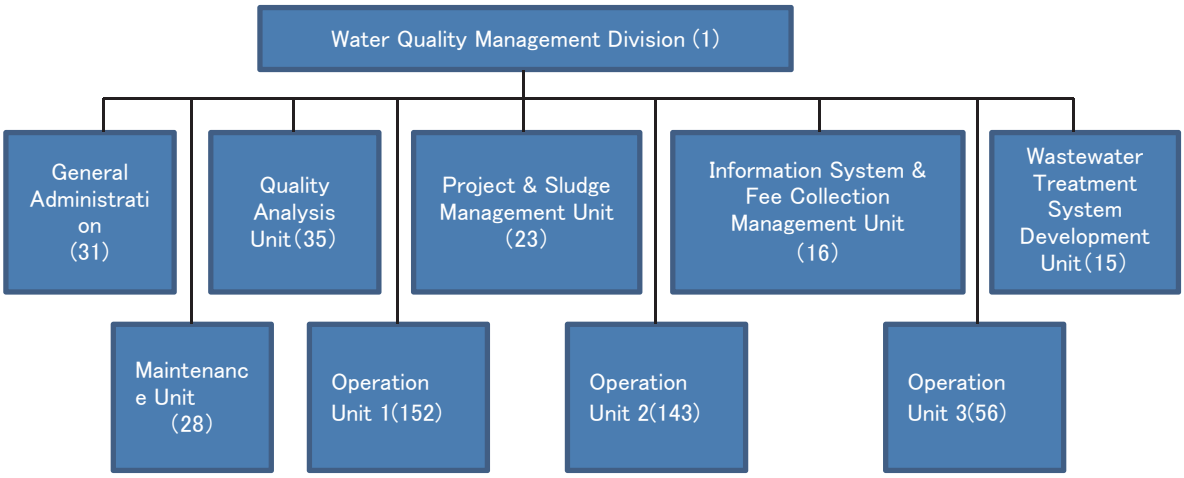


Figure 88 DSD Organization Chart

(3) Budget, Operation & Maintenance Cost, and Sewerage Charge

At present, operation and maintenance cost is covered by subsidies from government and taxes (Annual budget is three billion baht. Subsidy and tax ratio is 50:50). In 2004, regulation of sewerage charges was enacted, however collection has not been implemented as yet. This is because general public is dissatisfied with the current service rate of sewerage system, covering only 1/3 of the Bangkok area. DSD recognizes the necessity of collection sewage fees but they believe it is not collectable before sewered population reaches 60%.

(4) GIS

Sewer pipes information is managed using GIS. Though the same base maps as MEA or MWA are used, information is not shared with other organizations. As for large diameter sewer culverts, employees conduct visual inspections. On the other hand, as visual inspections cannot be provided to small diameter sewer culverts, DDS is planning to acquire inspection equipment. The main reasons for damages in pipelines are deterioration by aging or gas such as SO_2 generated from sewerage water.

Operation and maintenance of six treatment facilities and sewerage system covered by these treatment facilities are outsourced. According to BMA, they expected the installation of new technology by the private sector for operation and maintenance, however, it has not been materialized yet due to lack of revenue.

After the 2011 Southern Thailand Floods, improvement of infrastructure against flooding is a major issue for the Thai government. DSD is, therefore, seriously working for the improvement of both river embankment and sewerage system at present, because DSD is responsible for flood protection of Chao Phraya river as well.

(5) Current Status and Challenges of Asset Management

The improvement of infrastructure facilities against flooding has been one of the top priority issues in the infrastructure development in Thailand since the serious flooding in 2011. DSD of BMA, which is responsible for embankment of Chao Praya River, has been implementing inspection, maintenance and repair of the existing river embankment, focusing on leakage from the facility in particular. At the same time, BMA gives high priority to the improvement of drainage and sewerage systems, especially pipeline network and pumping stations for storm water and wastewater.

BMA recognizes the importance of operation and maintenance of existing facilities and makes an effort such as considering installing observation systems in the sewage pipes. The biggest issues BMA holds is not yet starting to collect sewerage charge which is essential for obtaining the financial resources necessary for operating and maintaining facilities due to the present low coverage rate of sewage system. Therefore, the top priority issue for the sewerage sector is to increase the coverage rate of sewerage system by developing the sewage system.

4.6.3 Wastewater Management Authority (MWA)

(1) Organization and Scope of Work

WMA is under MNRE (Ministry of Natural Resources and Environment) and managing sewerage system except Bangkok Metropolitan area. There are 60 employees are in Bangkok and 60 employees outside Bangkok. In Thailand, there are 101 sewerage facilities all together, and 8 are in Bangkok and 93 are outside Bangkok. Each facility is basically constructed and managed by municipalities in the district, however, WMA manages the sewerage facilities for some municipalities which cannot manage them by themselves. Generally, WMA manages facilities that are newly constructed or necessary to renew due to aging. In those cases, municipalities request WMA for support and WMA is going to support facility management for a maximum of 15 years if the request is approved.

What WMA assists is financial aid for new construction and supervision for facility operation and management. During 15 years of contract, WMA directly manages sewerage treatment facilities and when they face financial difficulties, they will ask for aid from the Thai government.

At present, WMA collects 30 baht per month from each family user unit to cover running costs. WMA manages 18 sewerage treatment facilities within Thailand.

The aim of WMA is to develop each municipality capacity to manage sewerage treatment facilities on their own through giving technical assistance for 15 years. Therefore, WMA never own sewerage treatment facilities. If a municipality obtains proper management skills within 15 years, WMA's support ends. However, up to this day, there is only one case whereby support was deemed unnecessary before completion of the 15-year contract period. The majority of municipalities expect to extend contract period.

WMA only manages sewerage treatment facilities and municipalities are responsible for extending sewer culverts and maintenance.

(2) Operation and Maintenance Condition

Life expectancy of sewerage treatment facilities is about 7 to 15 years, depending on materials used. As preventive maintenance, management organizations regularly oil or grease machineries or replace spare parts.

(3) Current Issues

The biggest issue is inadequate budget. In addition to that, there are only 120 employees which are not sufficient to meet increasing requests from municipalities.

(4) Technical Cooperation with Japan

As of 2014, WMA has technical support from Saitama Pref. Bureau of Sewerage and this year is the last year of a three-year project. Saitama Pref. Bureau of Sewerage is expecting to establish good relationships with municipalities and WMA through implementing this project for future business opportunities.

Saitama sewerage bureau is providing support in: field surveys, dispatch of engineers from Japan, and receiving trainees in Japan to enhance WMAs sewerage treatment skills, operation and maintenance skills, and problem solving skills.

(5) Current status and Challenges of Asset Management

The role of WMA is limited to technical assistance and WMA is not responsible for long-term operation and maintenance of facilities. Therefore, they lack interest in infrastructure management. Municipalities own facilities, however they depend on WMA's technical assistance for operation and maintenance. Therefore, they also lack interest in asset management.

Under such circumstances, the following measures can be effective.

For WMA, such technical assistance as provided by Saitama Pref. should be continued to enhance WMAs sewerage treatment skills, operation and maintenance skills. For municipalities, together with development of existing sewerage facilities, WMA should make them realize the responsibility of maintaining sewerage facilities in their municipality, and send engineers to provide training of sewerage treatment skills, operation and maintenance skills in order to enhance their sewerage facility maintenance level.

4.7 Railway Sector

4.7.1 Overview of the Sector

There are three main railway operators.

In 1896 State Railway of Thailand (SRT) started railway operation and covers the whole of Thailand.

In 2010 SRT's subsidiary, State Railway of Thailand Electrified Train (SRTET), started operation of 28.6 km Airport Link railway between downtown Bangkok and the Suvarnabhumi international airport.

In 2005 Mass Rapid Transit Authority (MRTA) started operation of a 20.8km subway in the Bangkok Metropolitan and contracted out its operation to Bangkok Metro Public Company Limited (BMCL).

In 1999 Bangkok Mass Transit Railway System Public Company Limited (BTSC) started operation of 36.92km elevated light railway transit system, known as Sky-train, in downtown Bangkok. Sky-train is owned by the BMA

Major commuting system in Bangkok used to rely on buses, however, to alleviate heavy traffic congestion caused by economic growth, subway and elevated light railway transit system were planned in the early 1990's, and started construction in the late 1990's.

4.7.2 State Railway of Thailand (SRT)

(1) Overview

1) Infrastructure facilities

SRT is responsible for operation and maintenance of 4 trunk railway lines 4,071 km with 1,000mm track width and another 12 branch lines.

Table 74 SRT Trunk Lines and Length

Line Name	Route	Length
North Trunk Line	Bangkok-Chiang Mai	KM.751+620
North East Trunk Line	Bangkok-Nong Khai Bangkok-Ubon Ratchathani	KM.623+900 KM.575+600
East Trunk Line	Bangkok-Aranyaprathet	KM.260+449
South Trunk Line	Bangkok-Sungai Kolok	KM.1,143+380

Note: Length shows single railway line track. Dual-track railway lines are counted twice.

Source: SRT

Figure 89 SRT Trunk Railway Lines

Source: SRT

SRT's infrastructure facilities are railway track, road subgrade, roadbed, railway yard, and safety facilities such as signal, railway crossing and railway switch.

At the total number of 440 railway stations nationwide, electric with color light signal systems (50%) mainly in Bangkok; manual railway switch with semaphore signals (40%). And remaining 10% do not have any railway switch and station workers use their hands to send signals (10%).

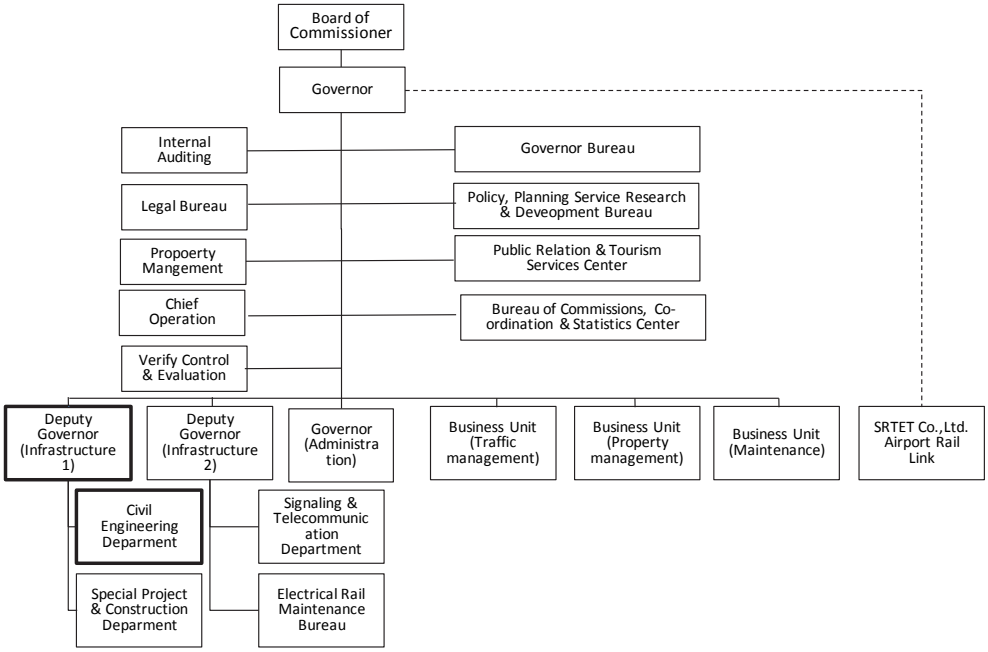
Among 2,500 railroad crossings nationwide, 90% are level crossing sections.

2) Organizations

In order to improve operation and erase SRT's chronic deficits, SRT restructured the organization in 2010 and established three business units, namely traffic management, property management and maintenance.

It may take time to coordinate two infrastructure maintenance related organizations because civil engineering sector (Infrastructure 1), and signaling & telecommunication and electrical rail sector (Infrastructure 2) belong to different lines.

For example, when track maintenance work requires the suspension of trains, coordination of civil engineering, electrical rail, and signaling departments is done not in the regional track maintenance center but in the property management unit in the headquarters, which sometimes takes time.



As of December 13, 2011

Figure 90 SRT Organization Chart

Source: SRT

3) Financial conditions

SRT suffered deficit for long periods. Maintenance cost is increasing although fare revenue is not increasing, which results in increase in deficit. In 2013, total revenue is 9.3 billion baht and operating expenses and maintenance expense of infrastructure and trains amounts to 7.0 billion baht and 7.1 billion baht, respectively, which accounts for 75% and 76 % of the total revenue, respectively. Moreover, interest payment is significant and amounts to 3.0 billion baht which accounts for 30% of the total revenue. Ministry of Finance establishes a special task force to discuss many problems and make concrete measures.

Table 75 SRT's Statement of Income

Unit : Mill baht

	2009	2010	2011	2012	2013	
Income						/ income (%)
Fare (Passenger)	4,308	3,997	3,933	3,696	3,700	40%
Subsidy foro fare	45	2,153	676	2,373	20	0%
Income from freight and others	4,262	4,966	5,332	4,996	5,579	60%
Total Income	8,615	11,116	9,941	11,065	9,299	100%
Expense						
Infrastructure Maintenance (Rail, Signal, Architecture)	1,591	2,059	2,619	2,514	3,885	42%
Rolling stock maintenance	2,519	2,630	2,850	2,982	3,298	35%
Operation	6,245	6,591	6,750	6,837	7,014	75%
Management	606	698	780	1,005	931	10%
Total Expense	10,961	11,978	12,999	13,338	15,128	163%
Operating income	−2,346	−862	−3,058	−2,273	−5,829	−63%
Repayment	942	925	934	945	933	
Depreciation	1,979	2,017	3,920	1,987	1,890	
Loan Interest	2,152	2,201	2,368	2,714	3,000	32%
Grand Total	−9,412	−8,175	−12,499	−10,406	−14,284	−154%

Source: SRT

(2) Maintenance and Repair

Around 100 derailment accidents occur every year, as shown in the following table because of aging of railway tracks and sleepers as well as troubles with trains, facilities and railway crossing operations.

Table 76 Number of Derailment Accidents

Year	2009	2010	2011	2012	2013	2014
Derail	94	102	113	89	125	57

Note: As of July 27 in 2014
Source: SRT

1) Plan

SRT makes and updates a 5 year track maintenance plan with rail, sleeper and railway switch. SRT was planning to invest in a 20 billion baht project for replacing railway tracks and sleepers in 21 sections from 2012 for three years, however it is not started yet.

Currently the following types of track rails are used.

Table 77 Type of Railway Track

Type of track rail (pound/yard)	Years since installation	Usage (%)
50	40-60	1.29
60	35-50	7.68
70	20-45	34.58
80	1-30	19.91
100	1-2	36.54
Total		100.00

Source: SRT

After the completion of this project, the light and old railway tracks will be replaced, and 100 pound/yard railway track usage ratio will be improved from 36.54% to 80 - 90 %.

As weight per length increases, the area of track to bear the weight of the train wheels increases and axial load stress per area decreases, which can contribute to extending the railway track service life. And heavier railway tracks enable stable and fast train operation and decrease the number of derailing accidents.

In this project, SRT will also replace sleepers from wood or two-box concrete to PC, whose life span is longer, up to 90% from 65.84% in the following table.

Table 78 Usage of Type of Sleeper

Type of sleeper	Usage (%)
Wood	29.11
Concrete (two boxes)	5.05
PC	65.84
Total	100.00

Source: SRT

For branch lines, there is no maintenance plan, however, SRT is planning to make a replacement plan in 3-4 years.

2) Implementation (Do)

SRT is replacing railway tracks from older sections and sleepers. It takes some time to collect necessary information because maintenance records are kept in excel and access format, and as-built drawings are separately kept on paper.

Since 27 years ago SRT has collected and updated railway track width and damages on sleepers by railway inspection car. SRT plans to procure another railway inspection car in a year.

Each track maintenance group is responsible for an average of 300km railway track maintenance section. A section director inspects for whole responsible section once a week, a senior inspector inspects for whole responsible section 3 times a week, and an inspector walks visual inspection for several divided units in each section once a day.

SRT has its railway track wear out replacement guidelines, and replaces tracks as suggested in the guidelines.

Section directors, senior inspectors, and inspectors inspect railway switch and railway crossing facilities by visual inspection, however, the number of accidents shows no improvement.

3) Evaluation (Check)

The civil engineering department keeps data collected using railway inspection car as a database in its original software, and analyzes the data and selects sections to be replaced.

SRT management executives cannot properly make business plans and allocate budget in accordance with the current organization structure as the system is not updated when organization was restructured.

Therefore, Asia Development Bank (ADB) implemented a one-year technical assistance project of "Accounting and Financial Management System Reform of Thailand's Railway Sector" since March 2013, to reestablish accounting system to match the current organization structure. ADB's recommendations include an operation management data center with hardware for 40 million baht and software for 80 million baht, which can timely supply basic data necessary for budget planning and decision making.

4) Review (Action)

Internal audit unit reviews and evaluates the maintenance report and give feedback to units in charge of operations and maintenance.

(3) Technical Cooperation by Japan

1) Yen loan program

SRT provided yen loans for railway car procurement project in 1981, railway construction projects in the eastern coastal industrial zone in the late 1980's, railway track improvement projects in the late 1990's, and ongoing Bangkok mass transit network project (Red Line). SRT will be in charge of operation and maintenance of Red Line.

2) Technical cooperation

Technical cooperation projects in the past are as follows.

- Elevated railway network in Bangkok metropolitan study March 1983 – July 1984,
- Railway operation field improvement study December 1985 – June 1987,
- Integrated study on railway transport improvement and urban development scheme for Bangkok metropolis August 1993 – November 1996,
- Railway training center project June 1992 – June 1997,

(4) Assessment of Current Asset Management Situation

SRT suffers from persistent deficits and over one hundred derailments every year. Its business operation is influenced by the government policy such as fare waiver program for low–income people. Currently the most important is to implement the 20 billion baht railway tracks and sleepers replacement project approved by the government in a few years from 2015.

Since the government established a special task force to improve financial situation so that priority of following their recommendations is higher for SRT than making and implementing holistic plans for asset management which requires long-term perspective, therefore, cannot expect immediate direct effects.

4.7.3 Mass Rapid Transit Authority of Thailand (MRTA)

(1) Overview

1) Service area

MRTA operates the 20.8km underground Blue Line with the 1,435 mm track width. The number of passengers is increasing by 5% every year since opening.

Extension work of Blue Line both to west is ongoing. Furthermore, two more lines, Purple Line is under construction, and four lines Pink, Orange, and Yellow Lines and extension of Green line, are in the planning stages. When these new lines are completed and railway network is expanded, the number of passengers is expected to increase more.

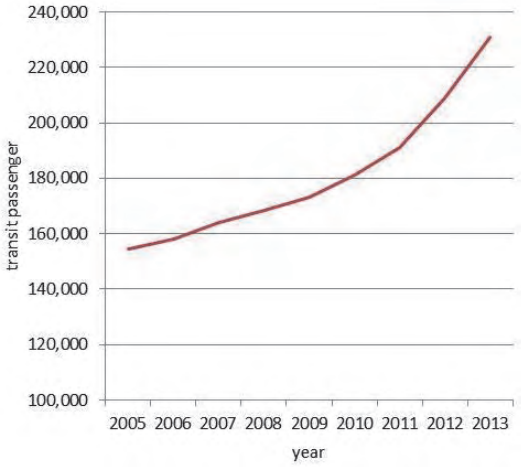


Figure 91 Trend of Number of Passengers of MRT Blue Line

Source: MRTA Annual Report 2013

2) Infrastructure facilities

MRTA owns tunnel, railway track and operation yard, and safety facilities such as railway switch and signal. MRTA has been outsourcing the operation and maintenance of the Blue Line to Bangkok Metro Company Limited (BMCL) since 2004 under a 25-year concession contract, and the BMCL conducts daily maintenance and inspection work for tunnel, railway track, and safety facilities.

3) Organizations

There are 806 staff in MRTA in total. Maintenance Division under the Operations Department is in charge of maintenance, and it reviews monthly maintenance report submitted by BMCL, which conducts operation and maintenance work under the concession contract..

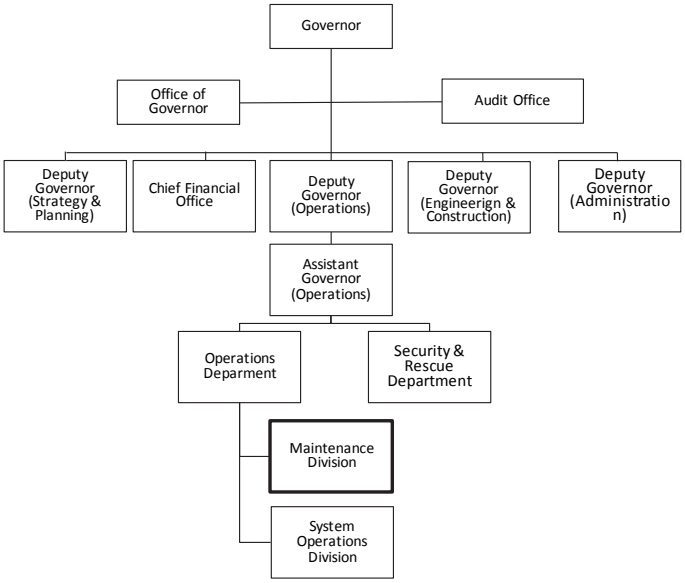


Figure 92 MRTA Organization Chart

Source: MRTA Annual Report 2013

There are 1,089 staff in BMCL in total, and BMCL focuses on asset management, and has a maintenance unit under each of civil and architecture, water systems and communications, as shown in Figure 91 and in charge of maintenance of tunnels, water leakage from tunnels, and communication systems, respectively. Each unit conducts inspections and maintenance and submits the results to MRTA through their monthly reports.

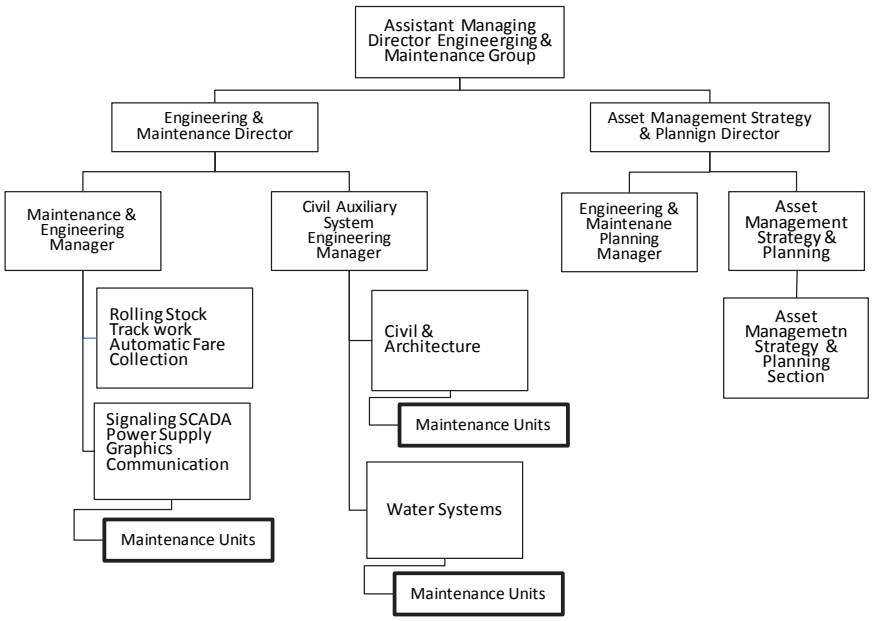


Figure 93 BMCL Organization Chart for Engineering and Maintenance Group

Source: MRTA

4) Financial condition

MRTA's financial performance was in deficit, however it yielded a profit in 2013, due to the exchange gains from Yen Loan[66] Cross Currency Swap and unrealized exchanged rate gains from the weakening values of Yen against Baht. Operating revenue before extraordinary items gradually increases and is 0.6 billion baht in 2013, however expense amounts to 3.4 billion baht, and about 1.4 billion baht excluding depreciation and amortization, which well exceeds operating revenue. Especially 0.85 billion baht finance cost is a burden.

On the other hand, MRTA suffered with exchange loss in 2011. MRTA's financial condition is affected by the foreign exchange fluctuation because most of its debt is in foreign currency. In order to improve this situation, MRTA intends to utilize currency swap to reduce the influence of foreign currency fluctuation. However, the improvement of main business performance is the most urgent issue.

Table 79 MRTA's Statement of Income

Unit: Mill baht

Item	2010	2011	2012	2013
REVENUES				
From subsides	396	441	398	430
From concession contract	27	31	46	80
From shop net	12	12	16	18
From approval to use real estates	17	28	32	40
From Park & Ride service fees	37	43	49	54
Total revenue from operation	489	556	542	624
Other revenues	25	27	44	35
Profit from sale of exchange rate	1,816		1,995	17,829
Total revenue	2,333	585	2,581	18,490
EXPENSES				
Personnel expense	440	280	322	430
Depreciation and amortization	1,898	1,905	1,917	1,916
Other expenses		179	177	191
Loss from exchange rate		9,187		
Financial cost	857	864	814	854
Total Expenses	3,195	12,417	3,231	3,392
Net income	-862	-11,832	-649	15,097

Source: MRTA Annual Report

(2) Maintenance Condition

1) Plan

MRTA obliges usage of maintenance guidelines under the concession contract with BMCL. BMCL makes asset management strategy based on its basic strategy, and develops total asset

[66] Remained repayment for Yen Loan is 33.35 billion yen, which is the large part of the liability.

management implementation plan throughout the life-cycle, annual integral maintenance plans, and action plans for individual facilities.

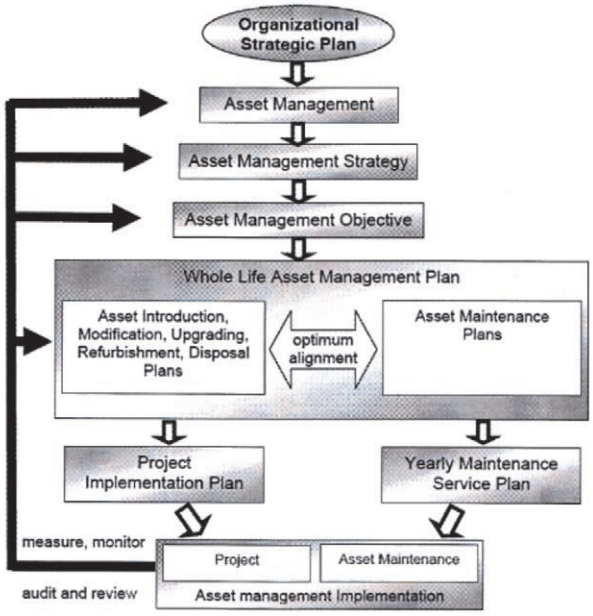


Figure 94 BMCL's Asset Management Strategy

Source: BMCL

2) Implementation (Do)

BMCL is ISO55000 certified and follows the asset management concept of preventive maintenance. The idea of PDCA is applied in case of contracting out to a contractor.

BMCL follows maintenance guidelines based on information provided by the manufacturing and construction company as designated in the concession contract with MRTA, and BMCL uses SCADA and SAP systems for operation and maintenance.

Track maintenance staff members inspect and maintain especially water leakage condition at tunnels and stations as daily maintenance during the night between the operation of the last train and the first train.

3) Evaluation (Check)

The essential and critical items, such as safety, reliability, are reviewed and improved by BMCL shown in Figure 93. When a defect is found in corrective maintenance by the contractors, MRTA reviews maintenance records and discusses remedial measures in contract management committee. When a defect is found in preventive maintenance, MRTA reviews the preventive maintenance plan, schedule, and preventive maintenance record form and check sheet and discusses measures in the functional performance meeting.

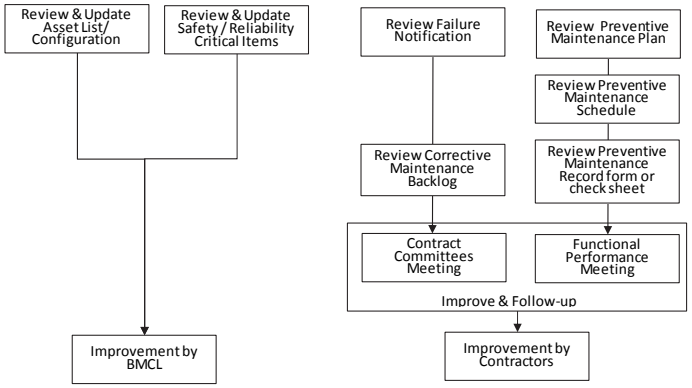


Figure 95 BMCL's Asset Management for Contractors

Source: BMCL

4) Review (Action)

BMCL has the internal review and evaluation committee, and evaluation results are reflected to the asset management strategy.

(3) Technical Cooperation by Japan

MRTA is financed 301.5 billion yen by yen loans for the construction of the Blue Line and currently the ongoing construction of the Purple Line from 1996 to 2012.

(4) Assessment of Current Asset Management Situation

Since MRTA operates and maintains only Blue Line opened in 2004, the facilities have been new and maintained in a good condition. MRTA contracts out maintenance and operations to BMCL with a 25-year concession contract, therefore, the MRTA's maintenance work is limited to review and approval of the performance of BMCL.

BMCL is implementing appropriate monitoring and evaluation based on its asset management strategy using a monitoring control system called SCADA. BMCL is ISO 55000 certified. No significant damage or aging problems are reported so far.

It is assumed MRTA currently does not have sufficient skills or experience for inspection and maintenance that will become necessary when the tunnels deteriorate with age, which may be an issue in future.

4.8 Electricity Sector

4.8.1 Overview of the Sector

There are three major electricity suppliers in Thailand. Electricity Generating Authority of Thailand (EGAT) is in charge of generation and transmission of electricity all over the country. Metropolitan Electricity Authority (MEA) is in charge of electricity distribution to the Bangkok Metropolitan and adjacent two provinces and Provincial Electricity Authority (PEA) distributes electricity to the rest of the country.

Since private sector companies can enter into the electricity business since the electricity power deregulation in 1992, various electricity type of enterprises entered into electricity generation business such as Independent Power Producer (IPP), Small Power Producer (SPP), Very Small Power Producer (VSPP) and Department of Alternative Energy Development and Efficiency (DEDE).

IPPs are either spin offs from EGAT or have been newly established, and generate 6,600MW in 2011. SPPs supplied 2,554 MW of power over 10MW up to 90MW to EGAT in 2012. Japanese electricity companies such as Chubu electric power, Kansai electric power, J-power and other electric companies are also in this market. SPPs are introduced to improving energy efficiency using co-generation system with conventional generators such as natural gas and coal, and renewable energy such as garbage, biomass, and photovoltaic, solar heating systems, and consequently to reduce import of crude oil. VSPPs are established to promote development of renewable energy and supplied 682 MW of power less than 10MW directly to MEA and PEA in 2012.

Electricity fare to end users is controlled under Energy Regulatory Commission (ERC) which was established in 2007.

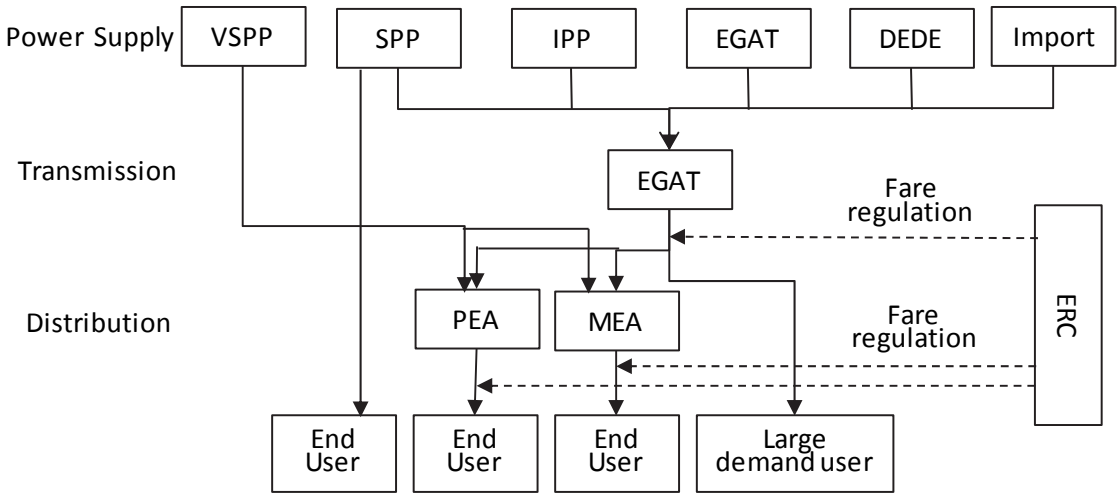


Figure 96 Structure of Electricity Market in Thailand

Source: Electricity market development in Southeast Asian Countries 2013, Japanese electricity corporation report

4.8.2 Electricity Generating Authority of Thailand (EGAT)

(1) Overview

1) Business summary

EGAT's power supply is gradually increasing to 155,207 MWh in 2011 along with economic growth of Thailand. According to the Thai Power Development Plan (PDP) in 2012, which is updated every 3 years, power demand will continuously increase up to 2030 after taking into account of economic indicators (NESDB estimated in 2011 that GDP will grow by 4.4% during 2012-2030) and effects of energy-saving and use of renewable energy.

Of the total power generated by EGAT, about 30% is sold to MEA and about 70% to PEA.

Table 80 Power Volume Supplied by EGAT by Buyer

Unit: MWh

Year	MEA	PEA	Others	Total
2007	43,597	93,159	2,689	139,445
2008	43,598	94,860	1,100	141,558
2009	43,221	95,390	3,081	141,692
2010	46,635	106,403	3,087	156,125
2011	45,766	106,391	3,050	155,207

Source: EGAT website

In order to increase power supply as electricity demand increases, the total length of transmission lines is increasing for large capacity of 230kv and 500kv.

Table 81 Length of Transmission Lines by Capacity

Unit : km

Year	115kv	230kv	500kv	Others	Total
2007	13,765	13,304	3,432	55	30,556
2008	13,458	13,277	3,432	51	30,218
2009	13,279	13,393	3,721	52	30,445
2010	13,352	13,541	3,721	25	30,639
2011	13,047	13,950	3,469	51	30,517
2012	13,561	14,060	3,884	51	31,556

Source: EGAT Website

Furthermore, EGAT has signed a memorandum of electricity trade with Malaysia, Myanmar and China, therefore electricity transmission network will be expanded to neighboring countries.

2) Infrastructure facilities

Main infrastructure facilities of EGAT are power plants and transmission lines.

Table 82 EGAT Main Facilities and Capacity

Facility	Capacity, Unit number
Thermal power plant	3 unit
Combined power plant	6 unit
Hydropower plant	22 unit
Renewable energy plant	8 unit
Transmission Line	32,384cct-km
Substation	213 unit

Source: EGAT website

3) Organizations

There were 22,000 staff members in 2012, which decreased from 35,000 in the early 1990's, due to downsizing of governmental entities during the Thai economic crisis.

EGAT separates organizations in charge of maintenance work for power plants and transmission network.

The Generation division operates and inspects power plant daily and also does simple repairs, and the Maintenance Center under the Business Development division implements large-scale overhauls and repairs. There are about 7,000 staff members in the Generation division including workers and 2,000 staff members in Business Development division. The Operation & Maintenance Business sectors support private companies which supply power to EGAT. For example, for IPPs only investing money, EGAT staff members in this division provide operation and maintenance of power plants.

Transmission System Maintenance division is responsible for daily maintenance and repair of transmission facilities.

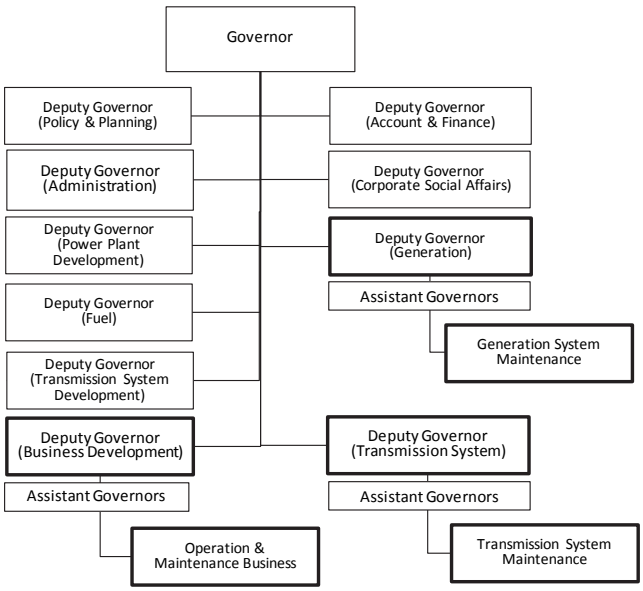


Figure 97 EGAT Organization Chart

Source: EGAT Website

4) Financial condition

In 2013 EGAT's revenue amounts to 536.9 billion baht (23.9 billion baht increase from the previous year), and gross profit amounts to 58.3 billion baht (0.8 billion baht increase from the previous year), and net profit amounts to 43.7 billion baht (0.4 billion baht increase from the previous year). The net profit ratio is 8%. Among the net profit, 21.3 billion baht of the amount is added to unappropriated retained earnings.

Table 83 EGAT Consolidated Statement of Income

Unit: Mill baht

Item	2013		2012	
Revenue from sales and services	536,913	100%	512,992	100%
Cost of sales and services	(478,659)	89%	(455,503)	89%
Gross profit	58,255	11%	57,489	11%
Other revenues	4,774		6,115	
Other expenses	(16,391)		(17,797)	
Financial costs	(4,417)		(5,343)	
Net profit	43,732	8.1%	43,338	8.4%
less non-controling interests	(3,390)		(4,480)	
Net profit for EGAT	40,342	100%	38,859	100%
Remmitance to the Ministry of Finance	19,060	44%	17,331	40%
Incrase in unappropriated retained earnings	21,282	53%	21,527	55%

Source: EGAT Annual Report 2013

In the fiscal year 2013 (dated December 31st, 2013) EGAT's total asset amounts to 578.4 billion baht. The fixed assets amount to 323.3 billion baht and it is 56% of the total asset. Its liabilities amount to 231.3 billion baht and equity amounts to 347.1 billion baht, which is 60% of the total asset. Among the equity, unappropriated retained earnings are saved as much as 224.7 billion baht, which accounts for 39% of the total asset.

Table 84 EGAT Consolidated Balance Sheet[67]

Unit: Mill baht

Item	2013		2012	
Assets				
Current Assets	185,374	32%	130,621	24%
Non-current Assets	393,006	68%	402,649	76%
Property, plant and equipment	323,311	56%	322,300	60%
Total Assets	578,380	100%	533,270	100%
Liability and Equity				
Current Liabilities	123,103	21%	91,923	17%
Non-current Liabilities	108,196	19%	116,373	22%
Long-term loans	71,735	12%	82,072	15%
Total liabilities	231,299	40%	208,296	39%
Owner's equity	347,081	60%	324,974	61%
Contribution from the government	9,002	2%	9,064	2%
Capital expenditure appropriation	80,186	14%	80,186	15%
Unappropriated retained earnings	224,710	39%	203,428	38%
Total liabilties and owner's equity	578,380	100%	533,270	100%

Source: EGAT Annual Report 2013

About half the EGAT assets are power plants, and together with transmission systems it amount to 200 billion baht or 77% of the total fixed assets.

[67] EGAT fiscal year terminates at the end of December.

Table 85 Fixed Assets and Depreciation Period (as of 2013 December)

Unit: Mill baht

Property, Plant and Equipment	Costs	Accumulated depreciation /impairment	Net book value	Depreciation period (years)
Land	8,574	0	8,574	
Structures	28,781	18,122	10,659	3-40
Reservoirs and dams	28,864	10,110	18,754	7-75
Power plants	334,775	212,423	122,353	5-30
Equipment for power plants	32,289	18,040	14,250	6-25
Control system	888	718	170	3-25
Transmission system	156,417	76,719	79,698	3-40
Communication system	6,915	5,735	1,180	5-25
Coal handling system	6,060	4,545	1,515	10-25
Machinery	6,387	5,101	1,286	5-10
Large-sized spare parts for mine equipment	43	43	0	8
Vehicles	3,035	2,466	569	5-12
Other materials and supplies	10,139	7,441	2,698	3-12
Deferred charge of major inspection fee	4,238	2,439	1,799	
Total	622,568	361,555	261,013	

Source: EGAT Annual Report 2013

By analyzing EGAT's 2013 financial indices, earning power is not very high but stable, as net profit ratio is 8%. Savings for investment for replacement of infrastructure facilities[68] shows that savings is about 30% of the accumulated depreciation expenses as cash flow from investing activities and cash and cash equivalent is 30% of accumulated depreciation and amortization expenses. The level of deterioration can be relatively high or depreciation period is shorter than actual useful life as 58% of costs of fixed asset are already depreciated.

Table 86 Major Financial Index

Assessment item	Index	2013
Earning power	Net profit ratio	8%
Savings for investment for replacement	Cash to be used for investment for replacement / accumulated depreciation and amortization expenses	30%
Level of deterioration	Accumulated depreciation / cost of fixed asset	58%

EGAT has stable earning power and no serious problem is found in either savings for investment for replacement and level of deterioration considering their maintenance management system.

(2) Maintenance and Repair

1) Plan

Maintenance sectors make a 7-year long-term maintenance plan and update it every year. As action plans they make daily, weekly, monthly, yearly maintenance plans, and these plans are always updated, and are used in maintenance.

[68] Cash to be used for investment for replacement / accumulated depreciation and amortization expenses, Cash to be used for investment for replacement = cash flow from investing activities + cash and cash equivalents + current investment

When EGAT first built power plants in 1970's, nobody had maintenance skills, therefore, EGAT faithfully followed maintenance procedures as suggested in the plant manufacturers' manual. They continue this way and request budget for implementing all tasks in the manufacturers' manual and receives budget as requested.

2) Implementation (Do)

Dams are maintained well through annual or biannual inspection work, even the oldest dam constructed more than 40 years ago is kept well without any water leakages. Power generation plants are properly maintained based on manuals prepared by plant manufacturers. There have been no accidents caused by insufficient maintenance so far.

Maintenance staff members in maintenance division under the Transmission System division, Generation, and Business Development are assigned and conducting maintenance properly.

When EGAT has too much overhaul or repair work for EGAT workers to handle, the maintenance sectors ask contractors for sending support workers.

3) Evaluation (Check)

EGAT uses several monitoring systems effectively such as, SCADA for transmission network control, Condition monitoring system for power plant operation condition, and Data Acquisition System for conditions after maintenance has been completed. For investigating the cause of failures, EGAT provides staff members for training programs on "Root Cause Analysis".

4) Review (Action)

EGAT makes maintenance reports, which are reviewed and evaluated by the internal audit committee, and the evaluation results are reflected to each maintenance unit.

Manuals prepared by plant manufactures have been kept and accumulated, and these have been adjusted to fit with EGAT conditions.

(3) Technical Cooperation by Japan

EGAT is financed total 106.5 billion by yen loans, to construct dams and power plants from 1970 to 1994 to meet with increasing electricity demand.

(4) Assessment of Current Asset Management Situation

EGAT implements inspection and preventive maintenance work well for power generation plants and transmission lines based on the manufacturers' manuals and no water leakages are reported, even from the oldest dams which are more than 40 years old.

Financial condition is also sound, and it can easily cover the maintenance cost. EGAT's unappropriated retained earnings are sufficient enough to invest in replacement or large-scale rehabilitation when necessary. Therefore, it is expected that EGAT is able to continue their thorough maintenance without any serious problems.

4.8.3 Metropolitan Electricity Authority (MEA)

(1) Overview

1) Business summary

MEA purchases powers from EGAT and sells it to end users in Bangkok and two adjacent provinces (Nonthaburi and Samuthprakarn) after stepping it down. MEA supplied 47,617GWh in 2013 to 3.295 million users, both of which, supply and user base, are increasing recently, as shown in the following figures.

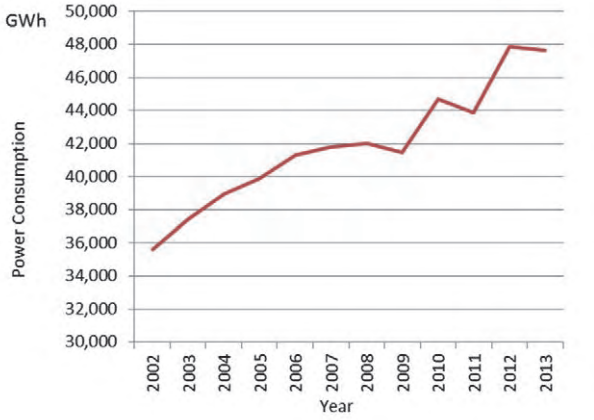


Figure 98 MEA Trend of Power Consumption

Source: MEA website

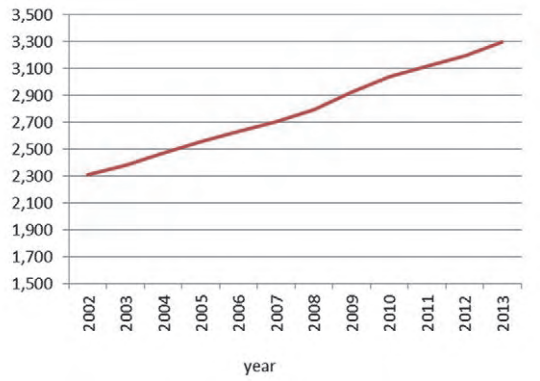


Figure 99 MEA Trend of Number of End Users

Source: MEA website

2) Infrastructure facilities

MEA's main facilities are substations and feeder lines (distribution lines).

Table 87 MEA Main Facilities and Capacity (2006)

Facility	Unit	Capacity
Terminal stations	17	15,200MVA
Substations	143	16,445VA
Sub transmission lines	-	1,622cct-km
Feeder lines	-	16,559cct-km

Source: MEA

3) Organizations

There were total 8,121 staff in MEA in 2012. Power System Planning Department with 350 staff members is responsible for maintenance planning and inspection of substations. There are 18 District Area Offices under the Distribution System Service Department and they are responsible for maintenance of feeder (distribution) lines in their area.

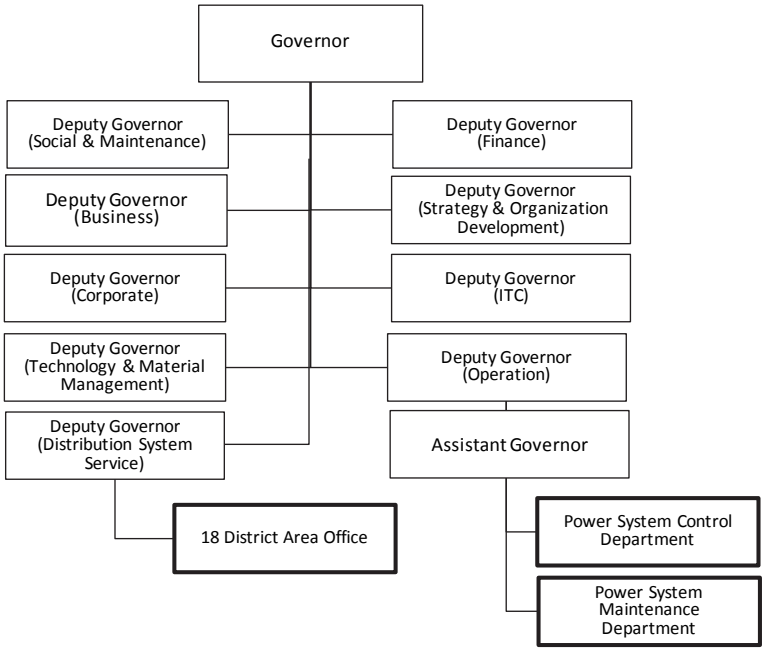


Figure 100 MEA Organization Chart

Source: MEA Website

4) Financial condition

The total revenue amounts to 178.4 billion baht (29.9 billion baht increase from the previous year), of which 97% is from sales of electricity. While total expenses amount to 169.0 billion baht (25.0 billion baht increase from the previous year), the net income yielded 9.4 billion baht (3.9 billion baht increase from the previous year) and net profit ratio is 5%. From the net profit, 45% is paid to the Ministry of Finance, and the remaining 51.9 billion baht is added to unappropriated retained earnings.

Table 88 MEA Statement of Income

Unit: Mill baht

Item	2012		2011	
Reveues				
Sales of electricity energy	173,880	97%	145,632	97%
Other income	4,532	3%	3,838	3%
Total revenues	178,412	100%	149,471	100%
Expenses				
Purchase of electricity	160,746	90%	136,208	91%
Operating expenses	5,917	3%	5,380	4%
Financial cost	1,372	1%	1,350	1%
Other expenses	968	1%	995	1%
Total Expenses	169,004	95%	143,934	96%
Net income	9,407	5.3%	5,537	3.7%
Remmitance to the Ministry of Finance	4,217	45%	2,521	46%
Incrase in unappropriated retained earnings	5,190	55%	3,017	54%

Source: MEA Annual Report 2012

MEA's total assets amount to 148.1 billion baht as of December 2012, consisting of fixed assets of 90.2 billion baht, which accounts for 61% of total assets. Total liabilities amount to 80.1 billion baht and total equity amounts to 67.9 billion baht, which comprises 46% of total assets and nearly all of them are unappropriated retained earnings, which is 67.6 billion baht. This rich accumulation of past profit implies a sound financial condition.

Table 89 MEA Balance Sheet 2011-2012

Unit: Mill baht

Item	2012		2011	
Assets				
Current Assets	47,259	32%	41,891	30%
Fixed Assets	90,208	61%	88,467	64%
Other Assets	10,593	7%	8,283	6%
Total Assets	148,060	100%	138,641	100%
Liability and Equity				
Current Liabilities	24,238	16%	18,912	14%
Lomg-term Liabilities	27,680	19%	29,370	21%
Other liabilities	28,208	19%	27,616	20%
Total liabilities	80,126	54%	75,898	55%
Owner's equity	67,935	46%	62,744	45%
Government contributions	358	0%	358	0%
Unappropriated retained earnings	67,576	46%	62,385	45%
Total liabilties and owner's equity	148,060	100%	138,641	100%

Source: MEA Annual Report 2012

Nearly half the MEA's fixed assets are distribution system and 80 billion baht or 89% are transmission system and distribution system. Depreciation period varies from three to 30 years depending on the type of property.

Table 90 MEA Fixed Assets (As of 2012 December)

Unit: Mill baht

Property, Plant and Equipment	Costs	Accumulated depreciation	Net book value
Land and land rights	2,810	0	2,810
Transmission system	56,822	22,153	34,669
Distribution system	84,742	39,503	45,239
Terminal stations and sub stations	1,980	0	1,980
Machine, equipment and vehicles	539	0	539
General assets	13,835	8,861	4,974
Total	160,727	70,519	90,208

Source: MEA Annual Report 2012

By analyzing MWA's 2012 financial indices, earning power is not very high but stable, with a net profit ratio of 5% as a result of MEA's business style of buying and selling electricity as demanded at the regulated prices. Savings for investment for replacement of infrastructure facilities[69] shows that savings is about one third of the accumulated depreciation expenses as cash flow from investing activities and cash and cash equivalent is 37% of accumulated depreciation and amortization expenses. The level of deterioration must not be that high as 44% of costs of fixed asset are already depreciated.

Table 91 Major Financial Index

Assessment item	Index	2012
Earning power	Net profit ratio	5%
Savings for investment for replacement	Cash to be used for investment for replacement / accumulated depreciation and amortization expenses	37%
Level of deterioration	Accumulated depreciation / cost of fixed asset	44%

MEA has stable earning power and no serious problem is found in either savings for investment for replacement and level of deterioration.

(2) Maintenance and Repair

1) Plan

MEA develops 1, 2, 4, and 5 year maintenance plans based on manuals provided by the manufactures, and implements maintenance works including overhaul of distribution system based these plans.

Maintenance plans of transmission system are prepared by 18 District Area Offices and approved by the Deputy Governor of the Distribution System Service division in the headquarters.

[69] Cash to be used for investment for replacement / accumulated depreciation and amortization expenses, Cash to be used for investment for replacement = cash flow from investing activities + cash and cash equivalents + current investment

MEA follows the international standard when they maintain the facilities

- ISO 9110: 2008 Quality Management System Accreditation for electrical power supply, installation and maintenance,
- ISO/IEC 17025: 2005 Laboratory Accreditation for the MEA laboratory room which provides electrical equipment testing and calibration services,

MEA also follows ISO9001.

2) Implementation (Do)

MEA aims for efficient maintenance and total optimization of operation and develops Enterprise Resource Planning (ERP) system to provide complete picture of the whole MEA by comprehensively managing all assets such as human resources, facilities, equipment, and financial resources.

Inspection of substations and distribution system is conducted by a group with one engineer, one technician, and three workers based on the manufacturer's maintenance manual. When repair or replacement is required, MEA contracts out repair and replacement work to highly skilled engineers under the supervision of MEA staff members.

3) Evaluation (Check)

MEA uses GIS since 10 years ago and SAP and SCADA systems for efficient maintenance. MEA has also developed a system to share information related to maintenance such as e-Document system and Logistic Management System, and uses them for efficient asset data updating and cost evaluation.

4) Review (Action)

MEA prepares quarterly maintenance reports and submits to the third-party Energy Regulatory Commission (ERC) established in 2007. Their review and evaluation is reflected into the MEA's maintenance plans.

(3) Technical Cooperation by Japan

MEA is financed by yen loans, 10.4 billion yen for metropolitan electricity distributing network expansion project in 1977, and 14.3 billion yen for the 230kv underground transmission cable construction project in Bangkok in 2003.

(4) Assessment of Current Asset Management Situation

MEA actively aims for efficient maintenance and total optimization of operation and develops Enterprise Resource Planning (ERP) system to provide complete picture of the whole MEA by comprehensively managing all assets such as human resources, facilities, equipment, and financial resources. MEA also used GIS since 10 years ago and SAP and SCADA systems for efficient maintenance. MEA prepares a management system to surely implement asset management such as submission of quarterly maintenance reports to the external energy control committee for their review and evaluation. Therefore, no serious problem is found to continue such efficient maintenance.

4.8.4 Provincial Electricity Authority (PEA)

(1) Overview

1) Business summary

PEA purchases power from EGAT, and after voltage step-down, PEA distributes to the end users by its own distribution lines in the rest of Thailand except Bangkok and the adjacent two provinces (Nonthaburi and Samuthprakarn). PEA's distribution coverage is 99% of whole of Thailand, and its management is divided into 12 blocks with 915 branches nationwide.

2) Infrastructure facilities

PEA's main infrastructure facilities are distribution lines, substations, and distribution transformers.

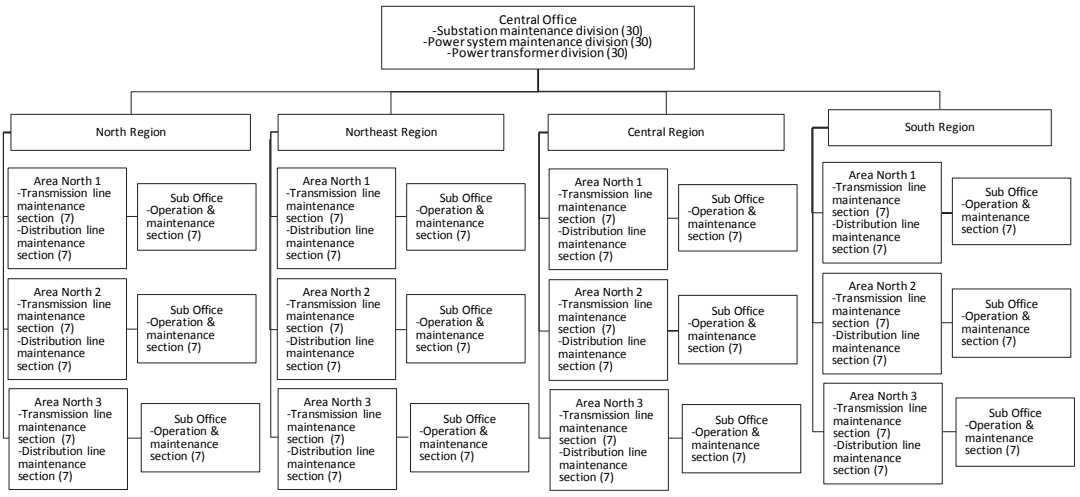
Table 92 PEA's Main Infrastructure Facilities

Facility	Capacity, Unit
High voltage distribution line 33/22kV	298,984cct-km
Low voltage distribution line 0.4/0.23 kV	457,118cct-km
Submarine cable	250cct-km
Substation	520 unit
Distribution transformer	270,000 unit

Source: PEA

3) Organizations

There are total 28,000 employees in PEA and approximately 5,000 employees are in charge of maintenance: 90 in the headquarters, 252 in the regional maintenance center and five in each of 915 branches nationwide. In the headquarters 30 staff members are assigned in each of the Substation maintenance division, Power System maintenance division, and Power transformer division.



( ): number of maintenance staff members

Figure 101 PEA Organization Chart

Source: PEA

4) Financial condition

Total revenue amounts to 375.2 billion baht (61.5 billion baht increase from the previous year), of which 97% is revenue from sales of electricity. While total expenses amount to 347.5 billion baht (59.9 billion baht increase from the previous year) and as a result, yielded a net income of 15 billion baht (2.5 billion baht increase from the previous year) with 4% net profit.

As with MEA, PEA purchases high voltage electricity from EGAT and sells it to end users, therefore, the revenue and expense ratios are stable. PEA financial situation is good and stable as electricity demand is expanding due to economic growth in the last several years, even though PEA is continuously investing in expansion of facilities.

Table 93 PEA Statement of Income

Unit: Mill baht

Item		2012		2011	
Revenue					
	Sales of electricity energy	375,188	97%	313,701	97%
	Other operating revenues	10,648	3%	9,824	3%
	Other income	2,326	1%	1,223	0%
	Total revenue from sales and services	388,163	100%	324,750	100%
Expense					
	Cost of sales and services	347,525	90%	287,673	89%
	Administrative expenses	17,350	4%	16,074	5%
	Selling expenses	4,958	1%	4,665	1%
	Other expenses	3,352	1%	3,875	1%
	Total Expenses	373,187	96%	312,288	96%
Net income		14,975	4%	12,461	4%

Source: PEA Annual Report 2012

(2) Maintenance and Repair

1) Plan

PEA has introduced PAS55:2008, and is developing an asset management roadmap to be certified according to the ISO55001.

PEA is trying to implement asset management based on the basic policy of optimal maintenance balancing Cost, Performance and Risk as shown below.

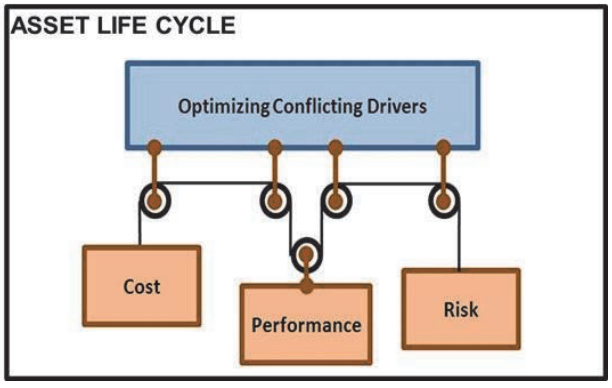


Figure 102 PEA's Basic Concept of Asset Management

Source: PEA

PEA develops asset management plans, long-term plans focus on Planning, Engineering and Procurement, mid-term plans focus on Analysis and Maintenance, and short-term plans focus on Construction and Operation.

Figure 103 Focus in Long, Mid, and Short-Term Asset Management Plan

Source: PEA

In the process of budget planning, each of the 12 regional blocks submit a budget plan to PEA headquarters, and the headquarters arranges budget plans based on maintenance history and replacement history for each facility.

2) Implementation (Do)

PEA conducts inspection, repair and replacement in accordance with the asset management plans.

3) Evaluation (Check)

PEA has been effectively utilizing several systems such as, SAP system for keeping maintenance history on facility maintenance management module and material management module, SCADA system for remote monitoring, GIS for connecting facility location and Operation and Maintenance System (OMS) for controlling troubles with facilities. These systems shift from visual inspection to automatic remote monitoring lead to efficient operation and management such as synchronizing inspection and improving objectivity.

4) Review (Action)

PEA is obliged to prepare quarterly maintenance reports and to submit them to the third-party Energy Regulatory Commission (ERC) established in 2007, for their review and evaluation.

Their evaluation results are reflected to PEA's maintenance operations.

(3) Technical Cooperation by Japan

1) Technical cooperation

Project Type Technical Cooperation: Training on Provincial Electricity Automation System Distribution Project

Cooperation Period: 1992 June to 1997 June

Cooperation: Technical transfer of basic technologies and knowledge about automation of electricity distribution and system development, operation, maintenance and application for capacity development for development and operation of automated distribution system.

2) Yen loan

PEA is financed 160.0 billion yen by yen loan for provincial electricity distribution projects from 1970 to 2002. These projects contributed to PEA's distribution network expansion so that the electrification ratio has increased from under 20% in 1970's to 99% in 1999.

(4) Assessment of Current Asset Management Situation

PEA implements asset management in accordance with PAS55:2008 of British Standard, and is developing an asset management roadmap to be certified according to the ISO55001. PEA succeeded in maintenance cost reduction by applying the asset management measures, which implies that PEA has well established and implements infrastructure management.

4.9 Evaluation Summary

4.9.1 Roads and Bridges

(1) DOH

DOH is responsible for the highways connecting main cities nationwide. The DOH budget has increased nearly 49% in five years from 2010 to 2014, and the budget for maintenance and repair has exceeded that for new construction since 2012. Even the new construction focuses on expansion of the existing roads since the total road length has been almost stable since 2002. Currently the priority of investment is shifting from new construction to maintenance and repair.

DOH is trying various attempts to strengthen capacity for maintenance and repair since 2000's. DOH started a road surface condition survey by using a road surface survey vehicle in 2007. In order to utilize the collected data in the pavement management system (PMS) it is currently accumulating data and improving a road surface degradation prediction method. In order to utilize PMS for PDCA management cycle, DOH needs to enhance the stakeholders' understanding of engineering maintenance management based on data.

As for about 15,000 bridges, database has been already developed, and DOH is collecting and accumulating data. In order to utilize this data in a future PDCA management cycle, DOH needs to overcome several issues such as training of inspection engineers, improvement of the accuracy of deterioration predictions through data accumulation and analysis and strengthening skills to use the analysis for planning.

For life extension of pavement, DOH is applying new low LCC road pavement technologies such as modified asphalt pavement and, on a trial basis, SMA pavement. In addition, DOH is offering regular training for maintenance technologies to its staff to raise their awareness.

As such, asset management operation structure is established in the branches. However, maintenance is not undertaken as scheduled due to budget and human resource shortages. For acceleration, capacity development at the top level and implementation of management based on the long-term strategy is a must. Furthermore, it is effective to prioritize maintenance by review of the top-level national plans and design standards.

(2) DRR

DRR is responsible for rural roads and its budget was 38,045 million baht in the fiscal year 2014, which was an increase of 71% over the five years from 2010 to 2014. Investment in rural roads is increasing.

For DRR, although importance of new construction is higher than that for DOH, the overall situation is the same that importance of maintenance is rapidly increasing and DRR undergoes various attempts for strengthening maintenance.

For maintenance of pavement, DRR installed PMS in 2005 and is using it for planning and implementation of road surface maintenance. Recently DRR has five road surface

condition survey vehicles and is accumulating survey data. In order to utilize this data in a future PDCA management cycle, DRR needs to overcome several issues such as training of inspection engineers, improvement of the accuracy of deterioration predictions through data accumulation and analysis and strengthening skills to use the analysis for planning.

As for about 8,000 bridges, JICA supported to develop maintenance manuals and bridge management databases through two technical assistance projects. DRR has inspected about 2,000 bridges and it may take another three years to complete the remaining 6,000 bridges.

DRR still gives priority to new road construction investment. As such, DRR suffers a shortage in maintenance budget and engineers skilled in inspection and maintenance. Most rural roads are not as congested as highways, however significant damage is recognized on heavily used roads.

DRR applies concrete pavement, which is about twice as expensive as asphalt pavement, on the stretches difficult to maintain because it lasts longer, which implies they consider LCC.

In addition, DRR is offering regular training for maintenance technologies to its staff to raise their awareness.

DRR and DOH are faced with similar issues regarding asset management. Asset management operation structure is established in the branches. However, maintenance is not undertaken as scheduled due to budget and human resource shortages. At the planning stage, database necessary for long-term planning is established, and currently DRR is accumulating data. From now on DRR needs to strengthen individual skills and organizations to utilize the data for long-term planning and implementation. For acceleration, capacity development at the top level and implementation of management based on the long-term strategy is a must. Furthermore, it is effective to prioritize maintenance by review of the top-level national plans and design standards.

(3) EXAT

EXAT is a state enterprise operating expressways in and around Bangkok by toll revenues. EXAT revenue is increasing every year along with its net profit, and the net profit ratio in 2014 was 45%. EXAT is paying back its loans as planned and subsidies from the government are drastically decreasing. EXAT's financial status is healthy. EXAT is set to spend 761 million baht on maintenance and repair in 2014, which accounts for 8% of the total expenditure including loan repayments.

EXAT is directly responsible for maintenance of 137km of expressways, which accounts for 66% of the total 207km of expressways. The operation and maintenance of the remaining parts are contracted out to two companies by concession contract.

EXAT undertakes inspection and maintenance based on manuals and accumulates a part of this data in their database. EXAT is developing a database for concrete elevated bridges, which are heavily used expressway structures.

It is said that EXAT's infrastructure facilities are healthy because they are short and still young, about 80% is younger than 20 years, and special care is paid to the maintenance of the two cable-stayed bridges. No serious maintenance problems are recognized except for parts generally vulnerable to damage.

However, its oldest concrete viaducts are more than 30 years old and damage may be recognized on RC slabs in future. The need to shift from corrective maintenance to preventive maintenance through sufficient inspections and maintenance of concrete viaducts is gradually increasing because it is troublesome and expensive to repair concrete viaducts. Special care in maintenance should be paid to joint sections of concrete viaducts.

Asset management structure for individual facilities has been established, however, it is necessary to strengthen management skills from comprehensive and long-term perspectives.

(4) BMA, Public Works Department

Public Works Department of BMA is responsible for construction and maintenance of municipal roads in Bangkok Metropolitan Area. As common for municipal roads used for community life, BMA undertakes corrective maintenance based on complaints, and BMA is trying to improve this situation.

BMA is also responsible for maintenance of more than 1,000 bridges, some of which are deteriorated. However, it is difficult to replace these bridges without causing a major inconvenience to traffic. It is therefore of utmost importance for BMA to undertake measures to extend the life span of its bridges. BMA uses various new technologies for inspection, maintenance, repair and reinforcement, nevertheless, this is all corrective maintenance as it is undertaken only after serious damaged has occurred.

BMA has accumulated enough data on its bridge database system and utilizes it well. Currently, BMA has just contracted out development of GIS-based bridge and road surface management system in September 2014 and it will take about two years to complete. In the meantime, BMA needs to further develop its database and strengthen skills to use data and to develop and implement long-term plans.

4.9.2 Waterworks

(1) MWA

MWA, which supplies water in the Bangkok Metropolitan Area, is self-supporting state enterprise in a sound financial condition. Without any government subsidies, it yielded a net profit of 700 million baht in fiscal year 2013. MWA spent about 4% of its total expenditure on maintenance.

MWA has almost fully expanded its water supply area and the coverage of the water supply system is expected to be 100% by around 2020. Their priority in business operation is not expansion of water supply area but maintenance such as improvement of water quality,

ensuring enough water pressure, and reduction of water leakage. Therefore, MWA is positively improving maintenance.

MWA uses SAP, integrated operation package system, business operation and GIS-based water pipe management system for its pipes, which account for 67% of its asset. These systems are used well by branch offices as well as planning and operation departments and repair records are immediately saved in its database. The quality level of pipe inspection and maintenance seems high. On the other hand, when it comes to purification plants which account for 20% of total physical fixed assets, SAP is underutilized at branch offices so that headquarters cannot access the latest information. In this regards, management skills should be improved.

Currently, even though water leakage rate has decreased to 24%, maintenance of MWA's water supply facilities can be further improved. This is because MWA is at the stage of improving its database through renewing pipes and updating information. Though MWA figures out high water leakage rate areas, sometimes MWA's request for permission to excavate under roads is not approved by BMA due to overcrowded traffic. We believe if MWA maintains its current inspection and maintenance procedures, data accuracy and water leakage rate will improve. Gradually they can change from corrective maintenance method to preventive maintenance.

In the late 2010s, more and more asbestos pipes will finish their life cycle, and in the late 2030s the majority of PVC pipes will finish their life cycle.

MWA needs to start developing a mid- to long-term plan to prepare for their replacement. Furthermore, MWA needs to develop a plan to minimize the LCC and to even out its replacement load. Since MWA's financial status is healthy, and human resources and data in database are sufficient, all they need to do is to develop a long-term asset management plan.

(2) PWA

PWA is a state enterprise responsible for water supply nationwide, in all areas besides Bangkok. It yielded a net profit of 19%, which is improving recently but it is still subsidized from the government.

Since PWA's service area covers the entire nation except for Bangkok Metropolitan, the priority differs according to area, in some areas the priority is expansion of water supply area and in other areas it has already shifted to maintenance.

PWA, as well as MWA, manages its waterworks system by GIS nationwide. Maintenance quality level of PWA's branch offices in the vicinity of Bangkok is as good as MWA. As PWA manages over 230 branch offices all over Thailand, the first priority is to improve maintenance quality level of all branch offices to the same level. As a solution, PWA contracts out maintenance works to a private sector at 20 branch offices. Contracting out is an important infrastructure management methodology and it is suitable for such

organizations as PWA with many branch offices. It is also important for PWA to develop its capacity to utilize private sector expertise for asset management.

PWA should develop long-term and integrated asset management plans and implement them as a possible effective way to manage water supply systems in large areas.

4.9.3 Drainage and Sewerage

(1) BMA, Drainage and Sewerage

Drainage and Sewerage Department of BMA is operated by subsidies from the central government and tax revenues from BMA. In fiscal year 2014, the annual budget was 3 billion baht and about half is from government subsidies and the remaining half is from BMA tax. BMA considers starting to collect fees when the sewerage coverage ratio exceeds 60%, which is currently about 30%.

Since sewerage coverage ratio is still low, the priority for BMA is to expand its service area. Moreover, the sewerage treatment facilities are still relatively new, therefore maintenance is not a priority issue.

Operation of six out of seven sewerage plants is contracted out to private companies together with connected pipes. They periodically inspect facilities and pipes, replace parts, and operate and maintain plants and pipes.

GIS is installed for sewer pipe maintenance to accumulate basic data of pipes and repair history. Moreover, BMA is proactively trying to install new technologies for better facility management such as remote control cameras to see current conditions of pipes.

BMA neither needs nor intends to proactively shift from corrective maintenance to preventive maintenance or to life year extension either for facilities or sewer pipes. Since it is difficult to repair sewer pipes deep under the ground, it is recommended to strengthen efforts for long-term asset management.

4.9.4 Railway

(1) SRT

SRT is a state enterprise in charge of operation and maintenance of nationwide national railways. SRT is suffering consecutive deficits and its debt increased from about 9.5 billion baht in fiscal year 2008 to 14 billion baht in 2013. Although income from passengers and freight transport is not increasing, expenditure for infrastructure and cars is increasing.

SRT has tried to improve railway lines through Japan's yen loans and to improve skills of railways maintenance and of driving through JICA technical assistance. However, progress is not good due to a significant influence by the governmental policy such as partial free ridership for low-income people and drastic layoffs.

There are problems with the inspection and maintenance systems, which is evident from the fact that there are approximately 100 derailments every year. In order to solve this situation, SRT received a 20 billion baht budget from the government for a railroad maintenance project to repair railroads in 21 areas. The project mainly aims to replace rails and railway sleepers. As PC ties have a longer life than the current materials, therefore this is expected to be a great improvement.

Despite the progress in maintenance, due to the poor financial situation, their policies are largely influenced by governmental policy, and their organizational problems, SRT can hardly implement asset management by itself.

(2) MRTA

MRTA is a state enterprise operating the first and only subway system in Thailand. Although MRTA yielded a profit in 2013 under special extraordinary circumstance, its deficit and subsidies from the government are increasing, and its financial condition is not good.

Since the subway was only inaugurated in 2005 their facilities are still new and in good condition. Since MRTA contracts out the operation and maintenance entirely to BMCL under a 25-year concession contract, MRTA only checks and approves maintenance as reported by BMCL.

BMCL conducts maintenance work such as monitoring and evaluation properly based on their asset management strategy. BMCL uses Supervisory Control and Data Acquisition (SCADA) for operation management and their asset management system is ISO55000 certified. According to examination data, there are no damages or deterioration, etc. reported, which means assets are in good condition.

On the other hand, it is assumed that MRTA and BMCL do not have much experience and know-how of inspection and maintenance of tunnels. In the long run, maintenance for tunnels may be an issue.

4.9.5 Electricity

(1) EGAT

EGAT is a state enterprise generating electricity in Thailand, and its financial condition is sound enough to allocate necessary budget for maintenance.

Major target facilities for EGAT are power plants and electricity distribution systems. They implement required inspections based on manufacturer's manuals. Their preventive maintenance methodology is working properly so that even some dam facilities that were built 40 years ago do not have water leakage problems. Their financial condition is also sound enough to cover their own maintenance costs. Their internal reserves are also sufficient enough to invest in large-scale repairs or replacement when necessary. As such,

they can work on continuous and stable maintenance. Judging from such a situation, EGAT is already pursuing systematic asset management.

(2) MEA

MEA buys electricity from EGAT and supplies it to end users in Bangkok Metropolitan Area. MEA's financial condition is also sound enough to allocate necessary budget for maintenance.

MEA has a maintenance division both in management and service departments and is proactively involved in maintenance. MEA developed GIS and installed SAP and SCADA 10 years ago and uses them for effective maintenance. In addition, they are obliged to submit maintenance reports every quarter to the outside energy observation committee for their review, which is a transparent mechanism to ensure continuous proper maintenance.

(3) PEA

PEA buys electricity from EGAT and sells it to end users in the rest of Thailand besides Bangkok. PEA's financial condition is also sound enough to allocate necessary budget for maintenance.

PEA's infrastructure management is already BSI PAS:2008 certified and follows its systematic work flow. Now PEA is preparing and following a roadmap to apply for ISO55000 certification. PEA is proactively making an effort to reduce costs by improving efficiency in maintenance.

5 Case Study on Infrastructure Management

5.1 Selection of Target Organizations

5.1.1 Conditions When Infrastructure Management Becomes Necessary

In the countries where the construction of new infrastructure facilities have started to decrease, the required maintenance cost increases due to the increase of infrastructure facilities and the required repair cost increases due to the progress of aging with facilities constructed in the initial development period. It finally leads to increase of accidents involving infrastructure facilities.

Moreover, people are no more satisfied with the basic service provided by infrastructure facilities and expect better services for infrastructure facilities such as no traffic congestion and safer pavement on rainy days in the road sector. As for water supply system, people come to expect continuous and stable water supply, enough water pressure, better water quality, etc. Therefore, although the investment in new facility construction declines, the investment responding to new demands becomes necessary.

If that time overlaps with the period of population decrease or decline of economic growth, the financial source constraints become even more severe and it makes the implementation of appropriate maintenance of infrastructure facilities very difficult. On the other hand, some infrastructure facilities become less necessary as a result of changes in society. The priority in the infrastructure facilities starts to shift from new construction to wise use of existing infrastructure. When there is a need to deal with such issues, there is an even greater necessity for infrastructure management as a tool for efficiently and comprehensively managing a wide range of infrastructure facilities. The conditions for the increase of the necessity of infrastructure management can be summarized as follows.

i. Infrastructure facilities that were constructed a long time ago are starting to age.

ii. The construction of new infrastructure facilities has started to decrease and the priority in the infrastructure facilities for the organization is shifting from new construction to maintenance.

iii. People are no longer satisfied with only basic services provided by infrastructure facilities and expect better services such as comfort, safety, convenience, etc. from infrastructure.

5.1.2 Assessment for Selection of Target Organizations

Target organizations of this study are all implementing organizations of one sector except for BMA. Therefore, holistic infrastructure management across these sectors should be based on national government's plans leading to specific actions. The role of national governments in Thailand, however, is to make policies and it is implementing organizations that make plans based on the policies. As such, the planning and budgeting organizations

are not aware of nor ready for their responsibility in infrastructure management. It is difficult to develop measures whose effect can be confirmed within the scope of this study. BMA is also not ready for leading holistic plans as roles related to infrastructure management are separated in many departments.

Considering the scope of this study and situation of target organizations, the Study Team selected priority sectors which are ready for asset management and developed measures for target organizations which could cooperate with this study. This process also intended to promote better understanding of infrastructure management by presenting the effects of measures confirmed through case studies and roles of asset management in infrastructure management in the seminar described in Chapter 6.

5.1.3 Selection of Priority Sectors

In the railway sector and the sewerage sector, the priority of new facility construction is still very high. In the transportation sector in particular, the priority of new construction of railways is very high in order to rectify the present condition under which road transportation is dominant. In SRT, around 100 accidents occurred every year due to many existing aging facilities and insufficient execution of maintenance. However, the improvement of institutional system is essential prior to strengthening asset management capacity because the causes of accidents are not only due to improper maintenance condition but also due to various improper functions of SRT. In addition, except SRT, the existing railway and the sewerage system were constructed not so long ago and their facilities service life are quite long, probably a few decades, therefore it is projected that the aging issue will appear after around 2035. Therefore, the necessity of infrastructure management is not high at present.

As for the electricity sector, a high priority has been placed on maintenance for many years because the electricity supply is extremely important for both economic activities and people's lives. In the electricity sector, therefore, they are actively executing asset management with a firm implementation system.

As for the water sector, the service coverage rate in the Bangkok metropolitan area has achieved nearly 100% and the rate in the whole country has exceeded 80%. The priority in water sector has been placed on maintenance. In addition, the state of directions for the state owned enterprises in water sector prepared by NESDB, prime minister's office and SEPO stipulates the importance of doing asset management in the operation. Currently, the state enterprises for waterworks have introduced the execution of asset management in line with the state of directions, however it has not been rooted yet in their operations. It is, therefore, understood to be still in the transition period.

As for the highway owned by DOH which represents the road administration in Thailand, the development of the highway network peaked more than 10 years ago and the new construction in the last 10 years have been mainly for widening the existing highways. In addition, the maintenance budget has been more than the new construction budget since 2011. These facts imply that the priority in the road sector is being shifted from the new

construction to the maintenance works and the expected services provided by highways has shifted from the basic service of accessibility to the decrease of traffic congestion, etc.

The present condition of each sector in terms of management of infrastructure facilities is summarized in the following figure.

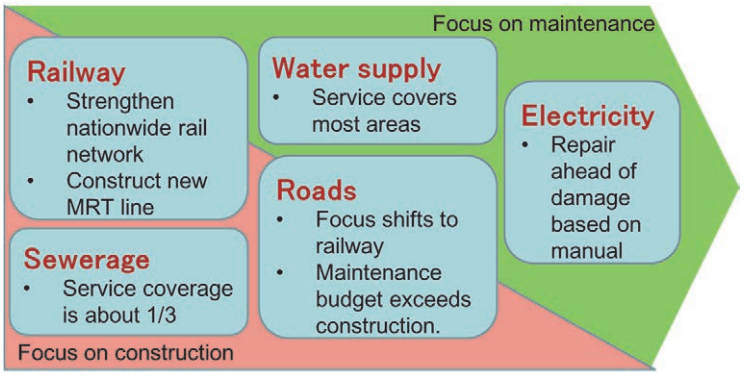


Figure 104 Present Condition of Each Sector in terms of Management of Infrastructure Facilities

Although asset management is assessed to be very important for every sector, the water sector and the road sector are selected as priority sectors in this survey based on the assessment result of each sector because asset management in these sectors is becoming very important.

5.2 Selection of Case Studies in the Priority Sectors

5.2.1 Basic Policy

(1) Target Organizations

MWA for the waterworks sector and EXAT for the road sector were selected as target organizations for Case Studies because both the management priority in both organizations is shifting from the new construction to the maintenance and the basic organizational system to implement asset management has been mostly arranged. In addition, an examination on the effects of revising road design standards is executed because such a revision was very effective in Japan.

(2) Focus Points

In order to present effective examples to clearly show to each infrastructure management organization the countermeasures within the capacity of this case study, the case study focuses on long-term perspectives on a few important issues to examine countermeasures, taking various circumstances and conditions for the organization into account.

(3) Objectives

The objectives of execution of case studies to examine the countermeasures are set as follows.

i. The case studies encourage stakeholders to understand the methodology of asset management planning and its importance by showing the cases to examine countermeasures to the forecast issues for the preparation of a mid- to long-term asset management plan from engineering and economic points of view.

ii. The case studies encourage stakeholders to understand the concepts and methodology of LCC in asset management.

iii. The case studies introduce some feasible technologies such as technologies to extend facilities life and new maintenance technologies etc.

iv. The case studies encourage stakeholders to understand that good infrastructure management and asset management give benefits to all stakeholders such as the infrastructure management organization, financial organization, and citizens.

5.2.2 Measures for Asset Management

The effects of measures are examined in the following three different cases.

1) Cases to examine the improvement of efficiency of waterworks operations

In Bangkok metropolitan area, the population has been decreasing since 2007. Although the number of users is increasing with the extension of the water supply area, it is expected for the increase of water demand and user numbers to slow down in future. As it will lead to slowdown in income growth from user charges, the long-term plan should be prepared for the implementation of countermeasures to overcome this problem, for example, by reducing the maintenance cost. The case study examines various measures by calculating their LCCs and proposes the best mix strategy.

2) Cases to examine the countermeasures to cope with the deterioration concrete structures due to aging

Most of the expressways in Bangkok metropolitan area are constructed using a concrete viaduct method. Although the condition of the concrete viaducts is still maintained in good condition due to proper maintenance and rather young structure, there is a high possibility for the maintenance cost to rapidly increase at some time in future when the age of the concrete causes deterioration. Therefore, the case study examines the long-term measures to overcome the problem by using the LCC analysis.

3) Case to examine the impact to LCC of road pavement by doubling the design useful years

In Japan, the revision of road pavement design standard made in 2001 was one of triggers to promote long life road pavement to reduce LCC. Case Study examined the impact to LCC of road pavement if it is applied to Thailand. It compares the LCC of road based on the present design standard with 15 year service life and LCC of road based on the 30 year service life design standard.

5.3 Case to Examine Countermeasures to Improve Efficiency of Water Supply Business

5.3.1 Background and Objectives

(1) Background

As the water supply area is expanding in the Bangkok Metropolitan and adjacent areas, both the number of users and water supply are increasing. The coverage of water supply system is nearly 100% and MWA is focusing on decreasing non-revenue water (NRW) by replacement of old pipes and repair of parts where water leakage is found, and NRW ratio dropped to 25%. Decrease in NRW contributes to operation cost saving because water production costs for leaked water can be saved.

It is expected that the increase in population in the service area will slow down in future. As it will lead to slowdown the income growth from user charges, more efficient operation by saving operation cost is desired.

(2) Objectives

By utilizing LCC analysis when selecting new pipe types for replacement, the most cost effective combination of pipe types are examined in terms of reduction of NRW ratio and water production costs.

5.3.2 Current Situation of MWA

(1) Water Supply Area

The water supply area of MWA is the Bangkok Metropolitan and two Nonthaburi and Samuthprakarn provinces. (See Figure in 4.3.2)

(2) Infrastructure Facilities

Among MWA'S fixed assets, pipes account for nearly 70%, which implies that maintenance of pipelines is important for maintaining the functional quality of the entire facilities. MWA also has pumps for water production and water pressure adjustment and water purification facilities.

Table 94 Breakdown of Fixed Assets

Item	Net book value (Mill baht)	% in fixed asset
Land	4,284.29	9.54
Building and improvements	6,769.90	14.95
Machineries and equipments	2,208.59	4.98
Pipes	30,413.88	68.81
Meters	579.93	1.25

Source: MWA Annual Report 2013

Pipelines are water conduit and water supply pipes (1,500-3,400mm), main distribution pipes (500 - 1,800mm), distribution branch pipes (100 - 400mm) and service pipes (under 75mm). The major pipes are distribution branch pipes (about 28,000km) and service pipes (about 5,600km).

Table 95 Length of Pipes by Type and Material

Unit:km

	ST	SCP	RCP	CI	PC-ST	PC	AC	DI	PVC	GI	HDPE	計
Water conduit and pipe (1500-3400m)	143.1				33.9	13.9						190.9
Distribution main pipe (500-1800mm)	1,436.5	35.1	18.7	98.3	45.4		7.6	3.4			7.3	1,652.1
Distribution branch pipe (100-400)	399.9			15.3			3,920.1		24,136.5	280.2	59.6	28,811.5
Total	1,979.5	35.1	18.7	113.6	79.3	13.9	3,927.7	3.4	24,136.5	280.2	66.8	30,654.5

* MWA also has service pipes of 5,600 km.

Source: MWA

About 92% of the distribution branch pipes (100 - 400mm) are poly vinyl chloride (PVC) pipes and asbestos pipes and the legal service lives in Thailand are 35 years and 25 years, respectively.

Estimating the length of PVC pipes and AC pipes to be replaced from now on, most AC pipes will reach their service life from now to 2030, and after that PVC pipes will reach their service life with a peak between late 2030's and early 2040's.

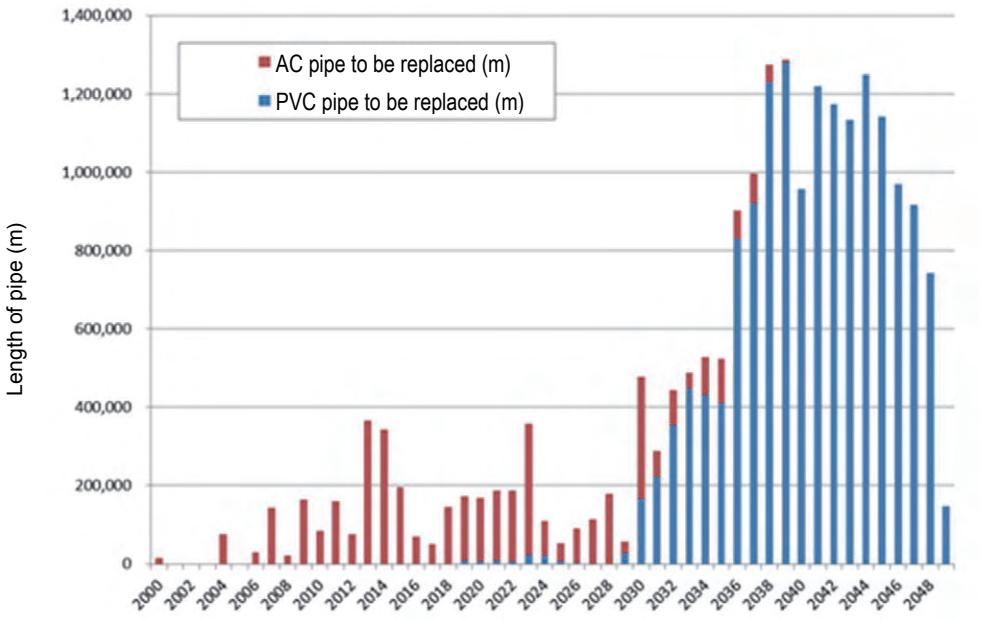


Figure 105 Length of AC Pipe and PVC Pipe by Year to be Replaced

(3) Non-Revenue Water Rate

The changes in volumes of revenue water and non-revenue water (NRW), and the share of NRW in total water produced for the last 10 years indicate that the share of NRW is decreasing since 2006 and about 25% in 2013.

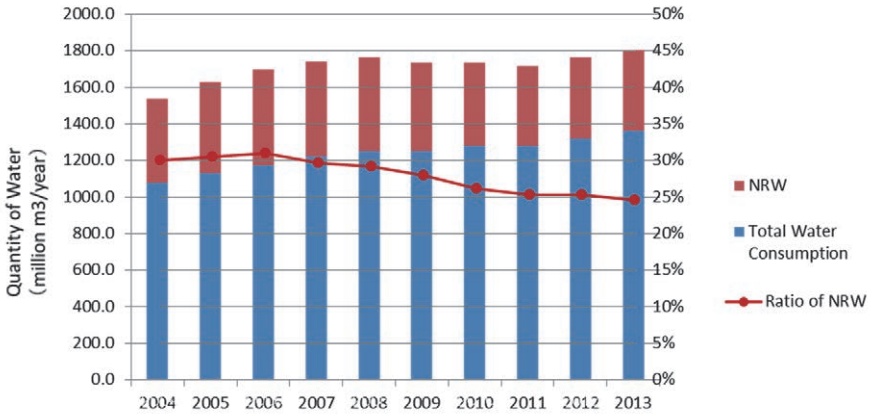


Figure 106 Changes in NRW, Total Water Consumption and Ratio of NRW

Source: MWA

About 60% of NRW leaks from distribution branch pipes and the remaining 40% leaks from service pipes.

Table 96 Length and NRW Ratio of Distribution Branch Pipe and Service Pipe

	Distribution branch pipe			Service Pipes		Total NRW ratio (%)(ii)	Service pipes/ Total NRW (%)((i)/(ii))
	Length (AC:km)	Length (PVC:km)	NRW ratio (%)	Length (km)	NRW ratio (%)(i)		
2013	3,920.05	24,136.51	14.68%	5,600	9.90%	24.58%	40.3%

Source: MWA

5.3.3 Issues related to Maintenance

(1) Low Population Growth

Population in the Metropolitan Bangkok is expected to continue increasing until 2025 and will start to decrease from there on, and population in two provinces will continue to increase however at a slower rate, which implies that the revenue from sales of water also stop increasing.

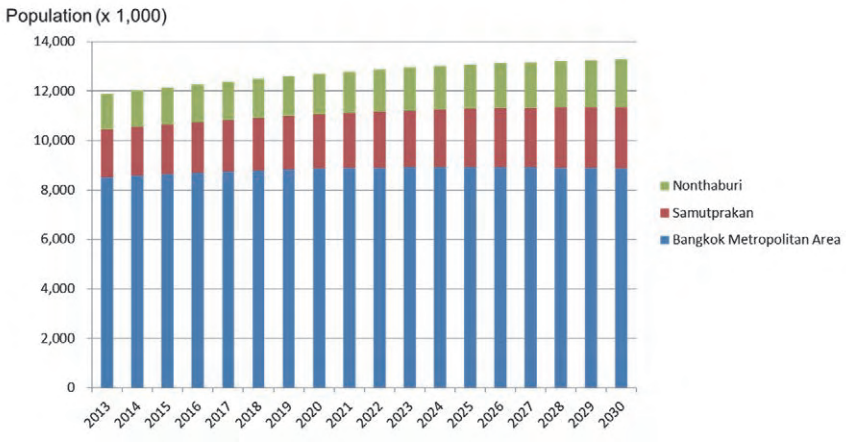


Figure 107 Changes in Population in the Water Supply Area

(2) High NRW Rate

Thanks to MWA's effort to replace AC pipes and repair of water leakage, NRW rate is decreasing for the last 10 years, but still it is 25% in 2013. The water production costs for the NRW is about 4.6 billion baht, which is equivalent to the half the net profit of 7 billion baht in 2013. This is a significant loss.

(3) Inefficient Pumps

Since the Bangkok Metropolitan is flat, there are many pumping stations to supply water throughout the water supply area. MWA is replacing pumps which should be replaced, however some pumps are continued to be used beyond the expected service life and such old pumps are inefficient. Power expense for operation of pumps was about 1.3 billion baht, which is about 73% of the electricity consumption in 2013. Efficiency of pumps directly affects operation and maintenance costs. Furthermore, users complain about low water pressure.

5.3.4 Basic Policy of the Case Study

Basic policies are set to tackle these issues. By replacing or repairing distribution and service pipes with water leakage, water production costs including electricity consumption for NRW will decrease so that operation and maintenance costs can be saved from a long-term perspective. This case study aims to maximize investment effect by operation and maintenance cost saving from reduced water production cost and electricity consumption and increase in revenue from expansion of water supply area. The following figure shows this concept.

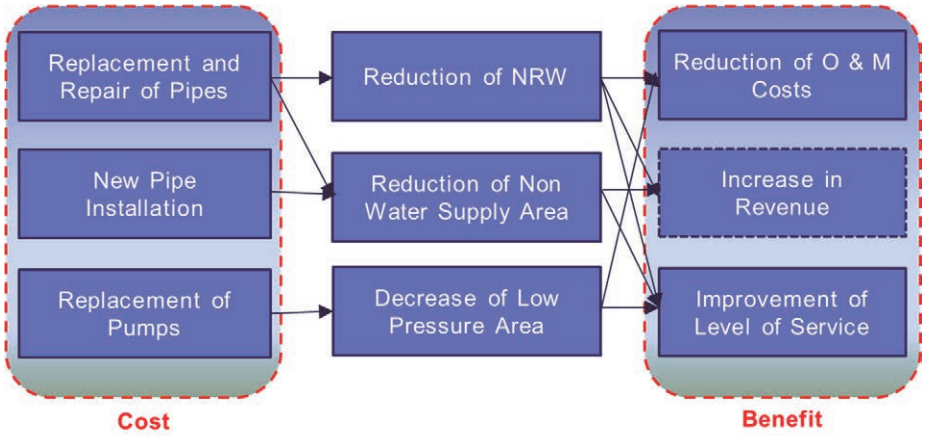


Figure 108 Basic Policy of the Case Study

In this case study cost benefit ratio is calculated where the cost includes replacement and repair of pipes, new pipe installation and replacement of pumps, and benefit includes reduction of operation and maintenance costs

5.3.5 Countermeasures

(1) Conditions of the Case Study

Target facilities: distribution branch pipes (100 - 400mm), service pipes (under 75mm), pump equipment

Target area: Whole water supply area of MWA

Target period: 50 years from 2015

(2) Outline of the Case Study

1) Scenario Structure

a) Pipe type

MWA develops its plan to install new pipes and replace old pipes. This is considered as the Baseline scenario and is compared with two scenarios. Scenario 1 uses PVC pipes when new pipes are installed and old pipes are replaced. Scenario 2 uses high density polyethylene pipe (HDPE: PE100) and ductile cast-iron pipe (DIP: NS) instead of PVC in some parts. Both HDPE and DIP have longer service life with less water leakage with the following characteristics.

Table 97 Characteristics and Usage in Scenario 2 by Pipe Type

Pipe Type	Characteristics	Usage in Scenario 2
HDPE	Water leakage is very low because thermal fusion using electricity forms firm joints. However, fusion work cannot be done in water so it is not possible to use along rivers. ● Application in Japan PN16 (Applicable water pressure: 16kg/cm2) is standard and service life is longer than 100 years. Applicable for pipes smaller than 200mm More common than PVC pipes ● Application in Thailand Few applications of PN10, which is thinner than PN16	In Thailand is used for pipes 200mm or smaller
DIP (NS type)	DIP is strong, durable, and resistant to mechanical shock. NS type is highly earthquake resistant because once jointed, lock feature prevents pipes from moving. ● Application in Japan Quake-resistant NS type is widely used. ● Application in Thailand DIP is rarely used, and in particular, NS type is not used. However, NS type will be applicable in soft ground in Bangkok because it can move in accordance with ground deformation.	In Japan is used for pipes over 200mm

Both HDPE and DIP are compared with PVC and the one with higher benefit over LCC is selected. The following tables show the comparison of cost (LCC) benefit ratio of 200mm pipe and 400mm pipe, which are typical sizes, and pipes with higher benefit over cost are HDPE for 200mm and PVC for 400mm. Here costs include pipe installation cost divided by the life cycle and benefit includes annual water production costs for leaked water savings by reduction of NRW.

Table 98 Comparison of Benefit over LCC by Pipe Type (200mm)

Pipe type	Life cycle	Cost (Baht/m)	Cost (Baht/m/year)	Benefit[70] (Baht/m/year)	Cost benefit ratio
PVC	35	1,251	35.7	39.0	1.09
HDPE	40	1,830	45.8	69.4	1.52

Table 99 Comparison of Benefit over LCC by Pipe Type (400mm)

Pipe type	Life cycle	Cost (Baht/m)	Cost (Baht/m/year)	Benefit (Baht/m/year)	Cost benefit ratio
PVC	35	2,968	84.8	39.0	0.46
DIP	40	12,933	323.3	74.0	0.23

However, HDPE is not applicable along rivers, which are common in Bangkok, because electric thermal fusion cannot be used in water.

It is not economic to always use DIP for replacement because DIP is more expensive and its cost benefit ratio is also lower than PVC. However, with its structural advantage of being able to be tightly locked, it is effective to use DIP for places difficult to replace such as major intersections and major roads to reduce occurrence of water leakage and repair.

b) Replacement of pumps

MWA replaces each pump when its useful life is over. This case study follows this method of replacing pumps when their service life is over. Some old pumps were made during 1970's and 1980's and thus pump efficiency is not high, about 60% or 70%. Replacement with new pumps will improve pump efficiency up to 80% or 90% at maximum. Given that pump efficiency of old pumps is 70% and that of new pumps is 80%, about 12% of power expense saving is expected.

[70] Benefit is calculated based on the following premise.
Benefit from replacement of pipes is the difference between annual water production costs for NRW per length from existing pipes (6) and from replaced pipes (5). Annual water production costs for NRW per length from replaced pipes = MWA's annual flow rate of existing pipes (1) x average annual NRW rate (2) x water production costs per m3 in 2013(4) . Here water production costs do not included electricity charge for operation of pumps.

Pipe type	Annual flaw rate (m3/m/year) (1)	Average annual NRW rate (%) (2)	Average annual NRW (m3/m/year) (3) = (1)×(2)	Water production costs in 2013 (Baht/m3) (4)	Water production costs from replace pipes (Baht/m/year) (5)	Water production costs from existing pipes (Baht/m/year) (6)	Benefit from replacement (Baht/m/year) (6)-(5)
PVC	53.62	8.69	4.66	8.16	38.0	77.01	39.0
HDPE		1.73	0.93		7.6		69.4
DIP		0.69	0.37		3.0		74.0

c) Outline of scenarios

Pipe types and replacement plans of the Baseline and two Scenarios are set as follows.

Table 100 Pipe Types and Replacement Plan by Scenario

Scenario	Policy	Distribution branch pipe	Service Pipe	Pump
Baseline	Follow MWA's own plan	Replace old pipes with PVC pipes based on MWA's plan	Not replace	Replace old pumps based on MWA's plan
Scenario 1	Replace pipes which end their service life with PVC pipes	Replace old pipes with PVC pipes when their service life is over.	Replace all old pipes	Replace old pumps based on MWA's plan
Scenario 2	Replace pipes which end their service life with PVC and HDPE or DIP	Replace old pipes with PVC or HDPE (80%) and DIP (10%) when their service life is over.	Replace all old pipes	Replace old pumps based on MWA's plan

The Baseline follows MWA's plan to replace old AC and PVC distribution branch pipes with new PVC pipes only and to replace old pumps with new ones when they reach their service life.

In Scenario 1, all distribution branch pipes are replaced with new PVC pipes when they reach their service life and old service pipes are also replaced in the entire water supply area. Replacement of pumps is the same as the Baseline scenario.

In Scenario 2, all distribution branch pipes and service pipes are replaced when they reach their service life. For distribution branch pipes, HDPE is used for 80% of pipes for 200mm or smaller and 10% of DIP is used for pipes over 200mm under the assumption that DIP is used only for important locations which are difficult to suspend traffic. Replacement of pumps is the same as the Baseline scenario.

2) Calculation Condition

a) Pipelines

- Timing of replacement is based on MWA's plan (Baseline scenario) and end of the legal service life applied in Thailand (Scenario 1 and 2). Japanese legal service life is applied for HDPE and DIP because there is no standard in Thailand.
- Operation and maintenance costs include repair and replacement cost of pipes and water production costs for NRW.
- Calculation of repair costs and water production costs for NRW is as follows.
    i) Water leakage ratio by age and by pipe type is calculated and weighted average of them makes the total water leakage ratio for the whole pipeline network.

ii) The number of water leaks and the volume of water leaks by pipe type for the year are calculated based on the water leakage ratio calculated in i). The repair costs and the water production cost for NRW are calculated using the number of water leaks and the volume of water leaks, respectively.

b) Pumps

- Timing of replacement is based on MWA's plan, which is the end of the legal service life applied in Thailand.
- Operation and maintenance costs include maintenance costs and replacement costs of pumps and electricity expense.
- Electricity consumption volume is calculated based on the water production volume.

(3) Basic Data used in the Scenarios

1) Revenue water

The forecast of the volume of revenue water are estimated based on the MWA's forecast of population in the water supply area up to 2030 and of water revenue up to 2022. The volumes of revenue water between 2023 and 2030 are calculated as a product of water supply per person in 2022 and the volume of revenue water after 2031 is assumed to be the same as 2030.

Table 101 Forecast of the Yearly Volume of Revenue Water

Year	Population in water supply area (thousand)	MWA forecast		Estimate		Yearly revenue water for Scenario (mill m3 /year)
		Yearly revenue water (mill m3 /year)	Water supply (m3/day/ person)	Yearly revenue water (mill m3 /year)	Water supply (m3/day /person)	
2015	12,146.5	1,416.5	0.320			1,416.5
2016	12,270.6	1,444.5	0.323			1,444.5
2017	12,388.8	1,471.5	0.325			1,471.5
2018	12,499.8	1,497.5	0.328			1,497.5
2019	12,604.1	1,521.5	0.331			1,521.5
2020	12,700.5	1,544.5	0.333			1,544.5
2021	12,789.8	1,566.5	0.336			1,566.5
2022	12,872.3	1,588.5	0.338			1,588.5
2023	12,947.7			1,597.8	0.338	1,597.8
2024	13,015.6			1,606.2	0.338	1,606.2
2025	13,076.9			1,613.7	0.338	1,613.7
2026	13,131.0			1,620.4	0.338	1,620.4
2027	13,179.5			1,626.4	0.338	1,626.4
2028	13,221.9			1,631.6	0.338	1,631.6
2029	13,257.8			1,636.1	0.338	1,636.1
2030	13,287.6			1,639.7	0.338	1,639.7
2031& later	13,287.6			1,639.7	0.338	1,639.7

2) Service life and the number of water leaks

The legal service life in Thailand and the actual numbers of water leaks per length recorded in MWA are used for AC and PVC pipes. For HDPE and DIP the legal service life in Japan

is used and the numbers of water leaks is estimated by reference to the research materials in MWA.

Table 102 Legal Service Life and Number of Water Leaks by Pipe Type

Pipe type	Service life	Number of water leakage (/100km/month)	Ground for calculation
AC	25	5.36	Past record in MWA
PVC	35	2.43	Past record in MWA
HDPE	40	1.24	Estimated by MWA
DIP	40	0.68	Estimated by MWA

Source: MWA

3) NRW rate

NRW rates of distribution branch pipe and service pipe are calculated in accordance with quadratic function based on NRW rates in 2013 and at the end of service life.

Table 103 NRW Rate of Distribution Branch Pipe and Service Pipe in 2013

Distribution branch pipe (%)	Service pipe (%)	Total NRW (%)
14.68	9.90	24.58

The NRW rate at the end of service life is set as 30.0% for AC pipe (25 years), 25.0% for PVC pipe (35 years), 5.0 % for HDPE (40 years), and 2.0 % for DIP (40 years). The NRW rate is assumed to change by age as follows.

Table 104 Change in NRW Rate by Pipe Type and by Age

Pipe Type	0 year	5	10	15	20	25	30	35	40
AC	0.00%	1.20%	4.80%	10.80%	19.20%	30.00%	40.00%	40.00%	40.00%
PVC	0.00%	0.51%	2.04%	4.59%	8.16%	12.76%	18.37%	25.00%	32.65%
HDPE	0.00%	0.08%	0.31%	0.70%	1.25%	1.95%	2.81%	3.83%	5.00%
DIP	0.00%	0.03%	0.13%	0.28%	0.50%	0.78%	1.13%	1.53%	2.00%

4) Water production costs

Water production costs are calculated using unit cost of water production costs except for power charge for operation of pumps, which is calculated separtaely, personnel costs, and the total volume of water produced calculated based on 1) revenue water and 2) NRW rate.

5) Pipe installation costs

Unit cost for pipe installation by pipe type and by pipe size is calculated based on MWA's past record, and this unit cost is used as replacement cost of pipes. For repair of pipes the cost is assumed to be equivalent to replacement of 6m of pipe.

Table 105 Pipe Replacement Cost by Pipe Type and Pipe Size

Unit (Baht/m)

Pipe type	Pipe Size (diameter)							
	50mm	75mm	100mm	150mm	200mm	250mm	300mm	400mm
PVC	―	―	575	879	1,251	2,059	2,471	2,968
HDPE	687*	1,177*	933	1,650	1,830	―	―	―
DIP	―	―	―	―	―	6,820	9,037	12,933

* Unit cost in Japan is used because there is no HDPE smaller than 100mm in Thailand.

Source: MWA

6) Installation of new pipes

MWA has installed about 1,000 km of new pipes a year for the last five years and expanded the water supply area. Even though the large expansion finished by 2014, MWA plans to continue extending its pipelines.

Table 106 New Pipe Installation Plan (PVC pipe)

	Planned new pipe installation by pipe size (km)						Total
	100mm	150mm	200mm	250mm	300mm	400mm	
2015	-	100.6	48.2	-	49.8	1.4	200.0
2016	-	100.6	48.2	-	49.8	1.4	200.0
2017	-	100.6	48.2	-	49.8	1.4	200.0
2018	-	95.5	45.8	-	47.3	1.4	190.0
2019	-	90.9	43.7	-	45.1	1.3	181.0
2020	-	86.5	41.5	-	42.8	1.2	172.0
2021	-	81.9	39.3	-	40.6	1.2	163.0
2022	-	77.9	37.4	-	38.6	1.1	155.0
2023	-	73.8	35.5	-	36.6	1.1	147.0
2024	-	70.3	33.8	-	34.9	1.0	140.0
2025	-	66.8	32.1	-	33.1	1.0	133.0
2026	-	63.3	30.4	-	31.4	0.9	126.0
2027	-	60.3	28.9	-	29.9	0.9	120.0
2028	-	57.3	27.5	-	28.4	0.8	114.0
2029	-	54.2	26.1	-	26.9	0.8	108.0
2030	-	51.8	24.8	-	25.7	0.7	103.0
2031	-	49.3	23.6	-	24.4	0.7	98.0
2032	-	46.7	22.4	-	23.2	0.7	93.0
2033	-	44.3	21.2	-	21.9	0.6	88.0
2034	-	42.2	20.3	-	20.9	0.6	84.0
Total	-	1,415.0	679.0	-	701.0	20.0	2,815.0

Source: MWA

7) Replacement of pumps

MWA intends to replace pumps when their service life is over. Judging from the current age and remaining service life, each pump will be replaced when its service life comes to end.

Table 107 List of MWA's Pumps

Pump Station	Number of Pumps	Elapsed Years	Pump Efficiency	Operation Hour (h/day)	Electric Consumption (kwh/year)
Sam Lae Pump Station No.1	-	―	―	―	10.480,560
Sam Lae Pump Station No.2	5	2-35	0.87	14.2	
Sam Lae Pump Station No.2A	3	19-26	0.88	23.1	
Sam Lae Raw Water Pump Station No.3	1	8	0.89	22	
Sam Sen Pump House No.1	―	―	―	―	22,179,000
Sam Sen Pump House No.2	5	12-22	0.74-0.81	11.3-14.9	
Sam Sen Pump House No.2A	5	12-21	0.74-0.81	11.00	
Sam Sen Pump House No.3	10	3-28	0.73-0.82	6.70	
Sam Sen Pump House No.4	3	45	0.70	6.70	
Sam Sen Pump House No.5	―	―	―	―	
Sam Sen Pump House No.6	3	28-30	0.72-0.73	11.00	
Sam Sen Pump House No.7	5	3-20	0.76-0.90	3.8-13.0	
Sam Sen Pump House No.8	16	2-20	0.68-0.82	3-23.5	
Sam Sen Pump House No.9	3	43	0.68-0.72	12-17	
Sam Sen Pump House No.10	2	3-43	0.78-0.90	5-19	
Sam Sen Pump House No.11	3	21	0.79-0.80	7-20	
Sam Sen Pump House No.12	5	21	0.78	1-22	
Thon Buri Pump House	6	26-28	0.68-0.72		2,841,356
Bang Sue Pump House	4	22-42	0.80	9	3,719,000
Bangkhen Raw water pump station 1	6	5-37	0.81	20.00	29,376,000
Bangkhen Raw water pump station 2	4	9-37	0.82	18.00	15,948,000
Bangkhen Transmission pump station 1	5	20-37	0.84	14.00	31,908,000
Bangkhen Transmission pump station 2	5	14-26	0.81	15.00	41,732,400
Bangkhen Transmission pump station 3	4	6-7	0.84	18.00	28,362,648
Bangkhen Distribution pump station 1	5	20-32	0.83	15.00	12,168,000
Bangkhen Distribution pump station 2	4	12-18	0.82	18.00	13,512,000
Bangkhen Wash water pump station 1	3	37	0.69	-	-
Bangkhen Wash water pump station 2	3	22	0.68	-	-
Mahasawat Raw water pump station 1	5	16-20	0.83	19.20	14,213,000
Mahasawat Raw water pump station 2	3	9	0.89	24.00	8,614,000
Mahasawat Distribution pump station	4	20	0.89	22.50	1,413,000
Mahasawat Transmission pump station	3	10-16	0.91	22.00	35,218,000
Lumpini Pump Station	4	35	0.75	13.75	8,400,000
Tha Phra Pump Station	5	35	0.76	5.60	2,461,284
Klong Toey Pump Station	5	30	0.77	7.20	5,952,012
Phahon Yothin Pump Station	―	―	―	―	―
Sam Rong Pump Station	5	26	0.76	17.4	13,392,012
Lad Phrao Pump Station	4	―	0.77	18.00	9,840,000
Lad Kra Bang Pump Station	4	―	0.77	14.75	7,944,000
Ratburana Pump Station	5	―	0.77	13.60	6,709,920
Phetkasem Pump Station	5	―	0.77	11.80	13,764,696
Bangplee Pump Station	5	―	0.77	14.40	10,968,000
min buri Pump Station	5	―	0.77	9.80	7,800,000
Total	180	―	―	―	326,267,328

Source: MWA

(4) Estimated Operation and Maintenance Costs and NRW Rate

1) Baseline scenario

Changes in operation and maintenance costs, which is composed of replacement cost of service pipes and distribution branch pipes, new pipe installation costs, and water production costs for NRW, and NRW rate for more than 50 years in the Baseline Scenario shows that NRW rate drops to 20%, which is not as much. Since 40% of water leakage occurs from service pipes, the water leakage reduction effect is limited without replacement of service pipes.

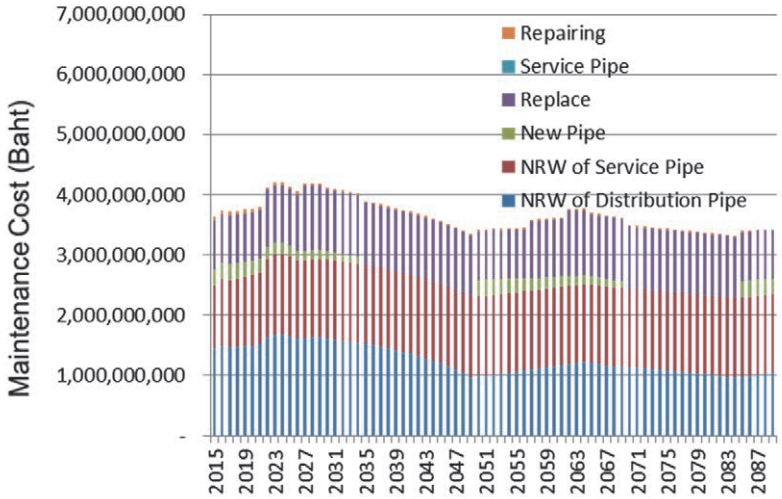


Figure 109 Change in Operation and Maintenance Costs: Baseline Scenario

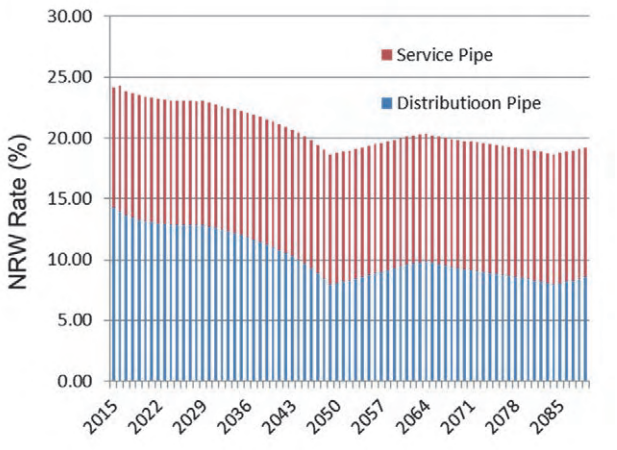


Figure 110 Change in NRW Rate: Baseline Scenario

2) Scenario 1

The NRW rate drops to about 10% thanks to replacement of service pipes together with distribution branch pipes. The effect of replacement of service pipes is significant especially in the area where water leakage from service pipes occurs often.

In addition, replacing with a large pipe from several small pipes running in parallel contributes to ease maintenance work, which is an effective measure for reduction of operation and maintenance costs.

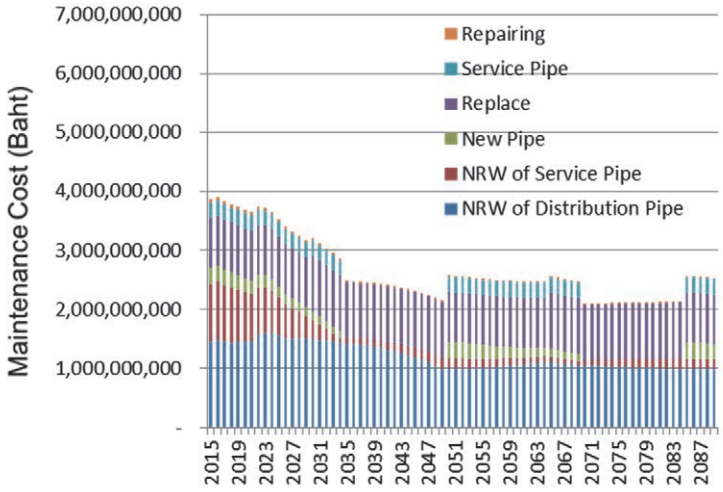


Figure 111 Change in Operation and Maintenance Costs: Scenario 1

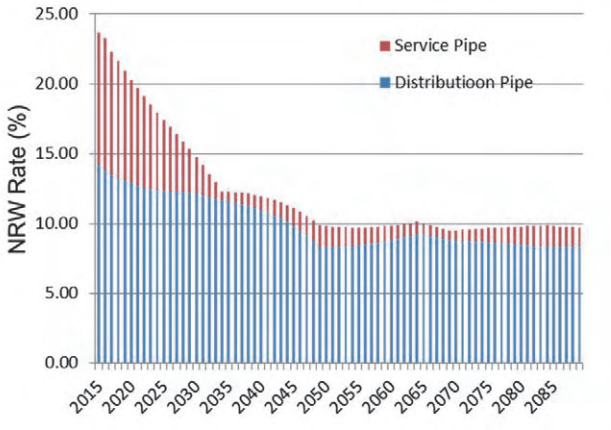


Figure 112 Change in NRW Rate: Scenario 1

3) Scenario 2

The NRW rate drops to about 5% by utilizing HDPE and DIP for some parts. In this case study the use of HDPE and DIP is assumed to be 80% and 10%, respectively, regardless of the actual site condition. This scenario shows that selection of suitable pipes for the ground and transportation conditions is effective for reducing NRW rate.

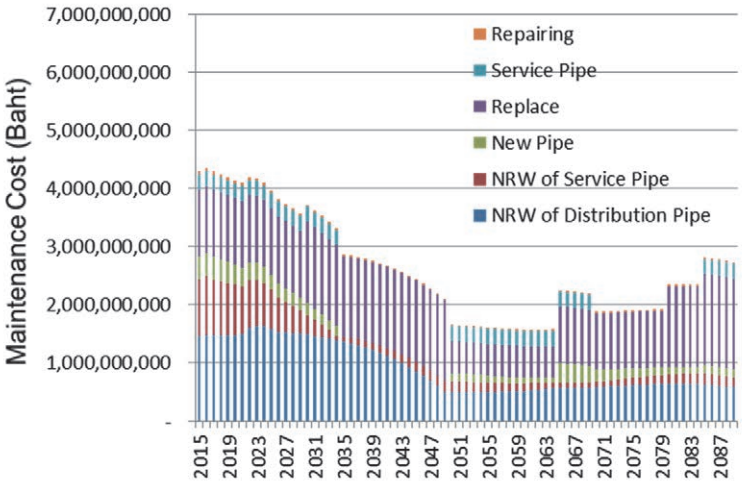


Figure 113 Change in Operation and Maintenance Costs: Scenario 2

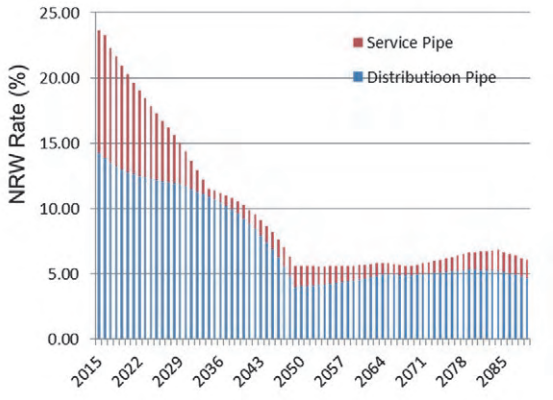


Figure 114 Change in NRW Rate: Scenario 2

4) Comparison of scenarios

Comparing the accumulated operation and maintenance costs for the three scenarios as illustrated in the graph, accumulated operation and maintenance costs in both Scenarios 1 and 2 are lower than those in the Baseline Scenario. This large difference is due to the replacement of service pipes, which contributes significantly.

Scenario 2 shows lower accumulated operation and maintenance than Scenario 1 costs after 2061, which implies that in the long run, use of longer-life and lower-water leakage pipes is cost effective even if the initial installation cost is higher.

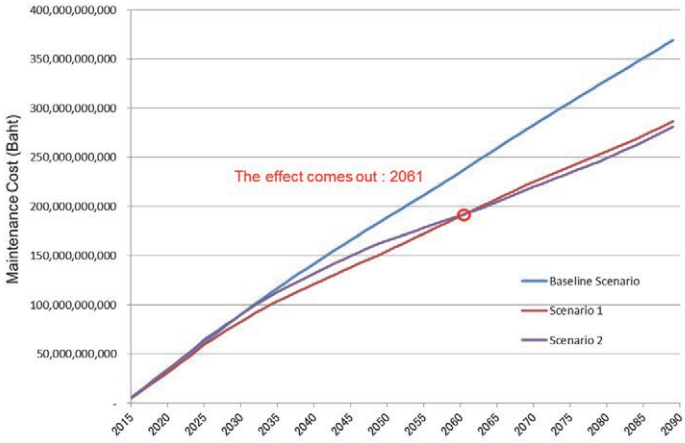


Figure 115 Accumulated Operation and Maintenance Costs for 3 Scenarios

Both NRW and NRW rate are the lowest in Scenario 2, followed by Scenario 1 and Baseline Scenario. It implies NRW can be effectively reduced by replacement of service pipes, which cause water leakage, and by use of longer-life pipes with lower water leakage.

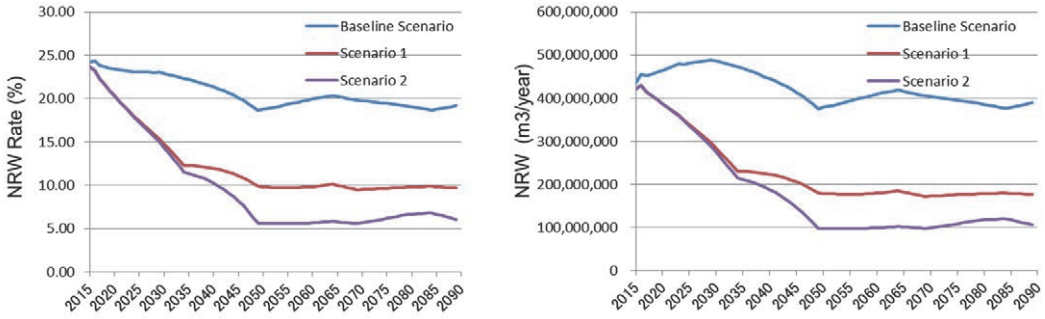


Figure 116 Change of NRW Rate and NRW for 3 Scenarios

Accumulated operation and maintenance costs for Scenario 1 and 2 shows the cost reduction effect compared to the Baseline Scenario is more than 40 billion baht. Especially with a small difference in costs, Scenario 2 achieves much lower NRW and NRW rate than Scenario 1, which implies that selection of pipes suitable for site conditions is effective for reduction of NRW.

Table 108 Accumulated Operation and Maintenance Costs and NRW Rate

Unit: Mill baht/50years

Scenario	Accumulated Operation & Maintenance (O&M) Costs	Difference in O&M Costs from BS	NRW Rate (%)	Difference in NRW from BS (%)
Baseline Scenario (BS)	188,105	-	20.35	-
Scenario 1	142,763	- 45,342	10.13	10.22
Scenario 2	140,994	- 47,111	5.83	14.52

5) Operation and maintenance costs of pumps

Operation and maintenance costs in this case study is composed of maintenance and replacement costs and power charge for operation of pumps. Power charges are calculated to multiply the total amount of water produced, electricity consumption per water production unit including efficiency improvement of pumps by replacement, and electricity fee. Since the replacement pattern of pumps is the same for the three scenarios, difference in maintenance and operation costs derives from the power charge affected by the total amount of water production.

In Baseline Scenario, electricity consumption will increase until around 2030 due to the influence of expansion of the water supply area is larger than decrease in water leakage and after that the power charge will turn to be stable at around 1.36 billion baht a year.

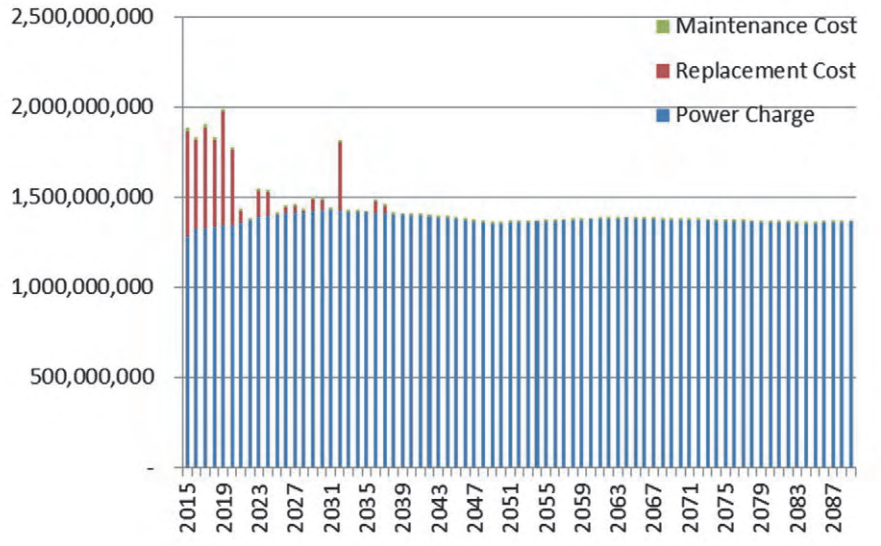


Figure 117 Operation and Maintenance Costs of Pumps: Baseline Scenario

In Scenario 1, although revenue water increases, decrease in NRW influences more than Baseline Scenario, power charge will be around 1.30 billion baht a year until 2030 and later on it will decrease to 1.22 billion baht a year.

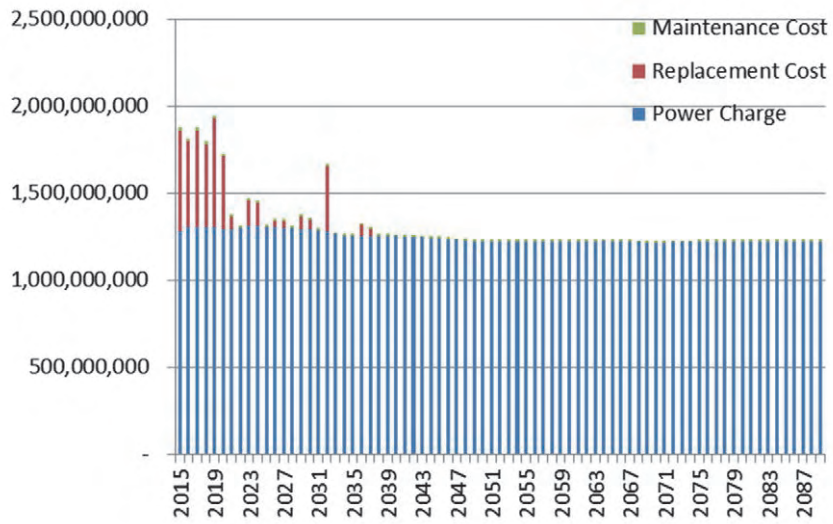


Figure 118 Operation and Maintenance Costs of Pumps: Scenario 1

In Scenario 2, the power charge will be about 1.30 billion baht a year and it will start decreasing from 2027 until 1.17 billion baht a year.

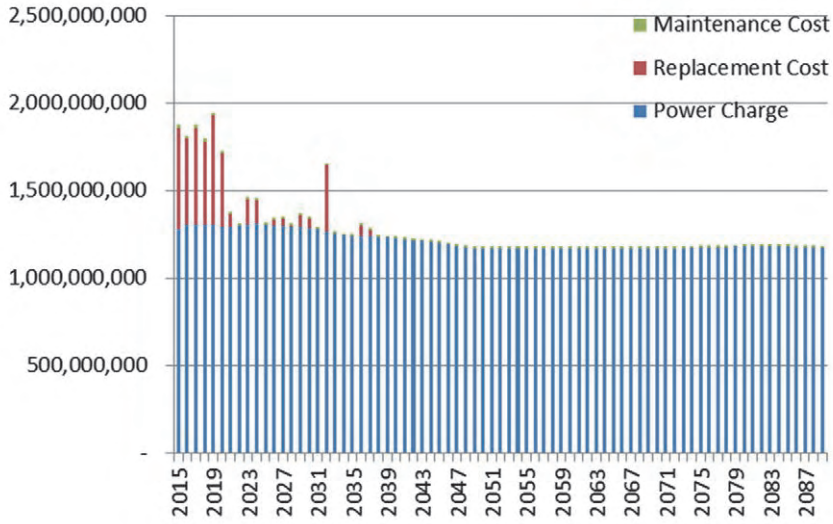


Figure 119 Operation and Maintenance Costs of Pumps: Scenario 2

The following graph shows the accumulated operation and maintenance costs of pumps for the three Scenarios together.

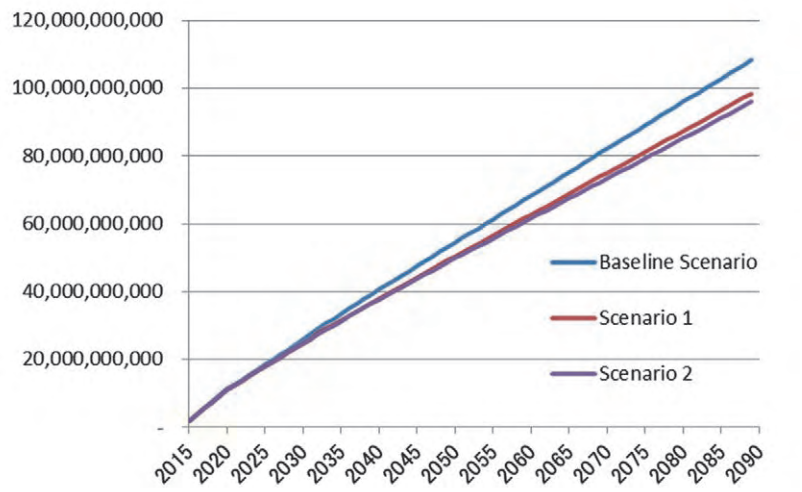


Figure 120　Operation and Maintenance Cost of Pumps: 3 Scenarios

Since power consumption by operation of pumps increases in proportion to amount of pumped water, electricity consumption decreases as the amount of pumped water decreases. NRW decreases in Scenario 1 and 2 compared to Baseline Scenario, power consumption also decreases and power charge can be saved by 8.4% (about 6.2 billion baht) in Scenario, 10.2% (about 7.5 billion baht) in Scenario 2.　Therefore, reduction of NRW can contribute to saving operation and maintenance costs of whole water facilities significantly.

Table 109　Accumulated Operation and Maintenance Costs of Pumps and Cost Savings by Scenario

Unit: Mill baht/ 50 years

Scenario	Accumulated operation and maintenance costs	Difference with BS	Savings compared to (%)
Baseline Scenario (BS)	73,803	－	－
Scenario 1	67,612	－6,191	8.4%
Scenario 2	66,266	－7,537	10.2%

Next, total accumulated operation and maintenance costs of the three scenarios are compared by adding those composed of 4) replacement costs of pipes and 5) replacement and operation of pumps.　The overall trend is the same and Scenarios 1 and 2 can achieve a large cost savings　effect compared to the Baseline Scenario, as can be seen in Figure 115 because the former, 4) the accumulated replacement costs of pipes, is much larger than the latter, 5) the accumulated operation and replacement costs of pumps.

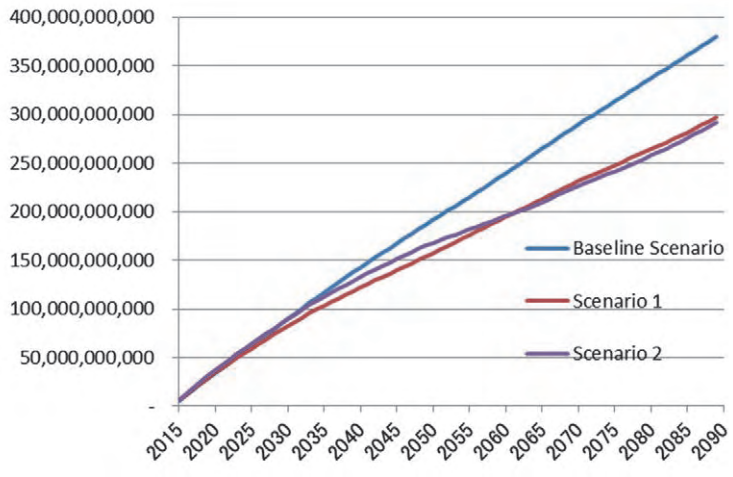


Figure 121　Accumulated Operation and Maintenance Costs including Pumps for 3 Scenarios

The cost benefit ratio of this study (cost savings of accumulated operation and maintenance cost of Scenarios 1 and 2 compared to the Baseline Scenario) is calculated as 20.0% for Scenario 1 and 20.9% for Scenario 2. And the accumulated operation and maintenance costs over the accumulated revenue for 50 years (1,097,144 million baht) is calculated as 20.0% for the Baseline Scenario, whereas 19.2% and 18.9 % for Scenarios 1 and 2, respectively, which are 1.6% and 1.9 % lower than that of the Baseline Scenario. Therefore, the impact on net profit ratio is considered as 1.6% for Scenario 1 and 1.9 % for Scenario 2.

Table 110　Cost Benefit Ratio and O &M Cost Ratio for Scenarios

Unit: Mill baht/50 years

Scenario	Accumulated operation and maintenance (O& M) costs			Difference from BS	Cost savings from BS (%)	Accumulated O &M costs/Revenue (%)
	Pipe	Pump	Total			
Baseline Scenario (BS)	188,105	73,803	261,908	－	－	20.8%
Scenario 1	142,763	67,612	210,375	－51,533	20.0%	19.2%
Scenario 2	140,994	66,266	207,260	－54,648	20.9%	18.9%

Note: The accumulated revenue over 50 years is estimated as 1,097,144 million baht.

The difference in the accumulated operation and maintenance costs for Scenarios 1 and 2 is 3.1 billion baht, where 1.8 billion baht is derived from replacement of pipes and the remaining 1.3 billion baht is from the difference in the power expense of pumps. Although the cost savings from the replacement of pipes are not as large as the expense of DIP, the reduction in water leakage contributes a lot in various ways such as electricity consumption.

In this study the replacement schedule of pumps are set as the same for three scenarios, however, the consideration of LCC of pumps when developing a replacement schedule can contribute further cost saving of maintenance and operation costs of waterworks system.

5.3.6 Findings

When selecting new materials and equipment such as pipe types, it is beneficial to compare LCC considering various environmental conditions and characteristics of the materials and equipment and select the best match for the locality. Such selection should be made based on a realistic maintenance plan from the long-term perspective and effectiveness of such plans should be assured by the implementation.

5.4 Case to Examine the Countermeasures to Cope With The Deterioration of Concrete Structures Due To Aging

5.4.1 Background and Objective

(1) Background

Most of the expressways in Bangkok metropolitan area are constructed using a concrete viaduct method and they are still maintained in good condition mainly because they are generally young; with 81% of structures having entered service less than 20 years ago. Because they are relative new facilities, and the structure is generally in a fine condition, the on-going inspection and maintenance remains at a basic level.

The inspection and maintenance of concrete structures tend to be ignored due to their very long service life, more than 50 years in general, and in addition due to the danger of the work in high places, especially in bridges. However, for example, if a concrete bridge has to be replaced due to aging, it is said that the required cost is more than double the initial construction cost because it additionally requires dismantling cost, processing cost for structure, and final disposal cost of debris. In addition, the implementation is very difficult because the land for construction work needs to be obtained and the disturbance to traffic during construction has to be managed.

However, if only basic maintenance is executed, the deterioration of the structure will progress gradually, and it will become necessary to do large-scale repair work at some point in time, which will lead to a rapid increase in maintenance cost.

(2) Objective

In order to minimize the required maintenance budget to be greatly increased in future due to aging of concrete structures, the alternative measures are examined by using LCC analysis to identify the optimum maintenance method.

5.4.2 Present Condition

(1) Facilities

EXAT manages 207.9 km of expressway within Bangkok metropolitan area and its environs. EXAT directly operates and maintains 137.9 km of expressway out of 207.9 km, and two concessionaires operate and maintain the remainder, 70.4 km.

Table 111 Length of Expressway by Organization in Charge of Maintenance

Execution organization	Road length (km)
EXAT	137.5
BECL	38.4
NECL	32.0
Total	207.9

Most parts of EXAT expressway is elevated bridge type and the facilities are understood to be generally new because 61% of all expressways were constructed between 10 and 20 years ago.

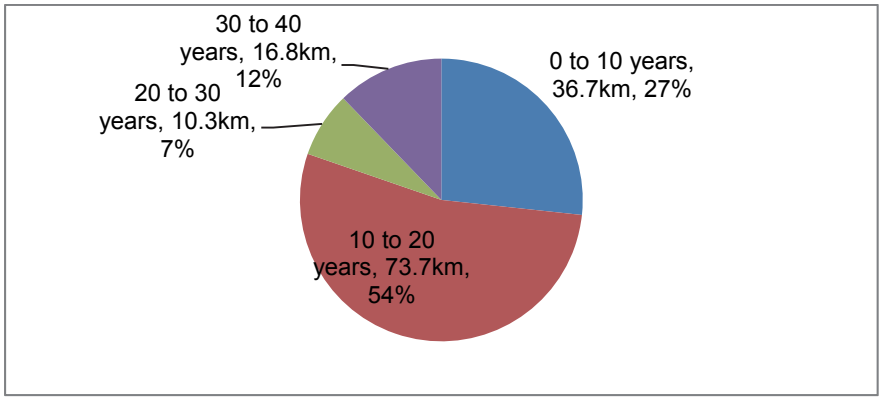


Figure 122 Classification of EXAT Expressway by Service Years

Table 112 Data of Expressway

No	Name of roads	Open year	Road length(km)	Length of elevated bridge part (km)
1	Din Daeng Port section	1981	8.9	4.9
2	Bang Na port section	1983	7.9	3.9
3	Dao Kanong port section	1987	10.3	10.1
4	Ram Inthra at KM 5.5 to Narong	1996	18.7	18
5	The Burapha Withi expressway	2000	55.0	55.0
6	The Bang Na-At Narong Expressway	2005	4.7	4.7
7	The Bang Phli-Suk Sawat Expressay	2007	22.5	22.5
8	Ram Inthra road linking to Outer ring road connecting to Chalong Rat expressway	2009	9.5	9.5
	Total road length maintained by EXAT		137.5	128.6

It is assessed that the condition of concrete structures is in sound conditions and the deterioration speed of concrete is slow and this is due to them being generally new, few temperature differences, little salt damage by sea breeze, etc. Therefore, only basic maintenance is successfully executed at present.

5.4.3 Identification of Problems

The problems with EXAT expressway to be forecast are identified.

■ Progress of the deterioration of concrete structure

The deterioration of the concrete structures will surely progress, although it is maintained in sound condition at present. However, it is too difficult to be reconstructed because it gives

large negative impacts to the society and economic activities for a few years during the reconstruction period.

- The rapid increase of required maintenance budget

The maintenance cost for concrete structures will rapidly increase with the progress of deterioration of concrete, although the facilities can be currently maintained in an appropriate condition with little maintenance cost.

5.4.4 Setting Basic Policy

The basic policy to propose measures against problems are set as follows.

- To take measures to reduce deterioration of concrete structures.
- To minimize the required maintenance budget which is expected to increase rapidly in future.

5.4.5 Examination of Countermeasures

(1) Facilities to be examined

RC slab is one part of a bridge's structure that is easily degraded. The case study, therefore, focuses on the maintenance of RC slab because it directly supports the vehicle weight and it is easily damaged.

An example of deterioration of RC slab is shown below.

1. Cracks appear on road surface.	2. Concrete under pavement has become powder.	3. Re-bars are exposed after powder is removed.

Figure 123 An Example of Deterioration of RC Slab

(2) Conditions for Case Study

- Target segment: Concrete elevated bridge parts which are directly operated and maintained by EXAT. The length is 128.6 km.
- Target facility: RC slab of concrete elevated bridge
- Study period: 100 years

(3) Concept of Case Study

The effect of maintaining concrete structures, in particular, is highly dependent on the timing of execution. If the structure is repaired after it reached the performance limit, the performance cannot be fully recovered and the life extended is shorter than the original life. On the other hand, if the structure is repaired before it reaches the performance limit, the performance can be fully recovered and the service life extended can be the same as the original life.

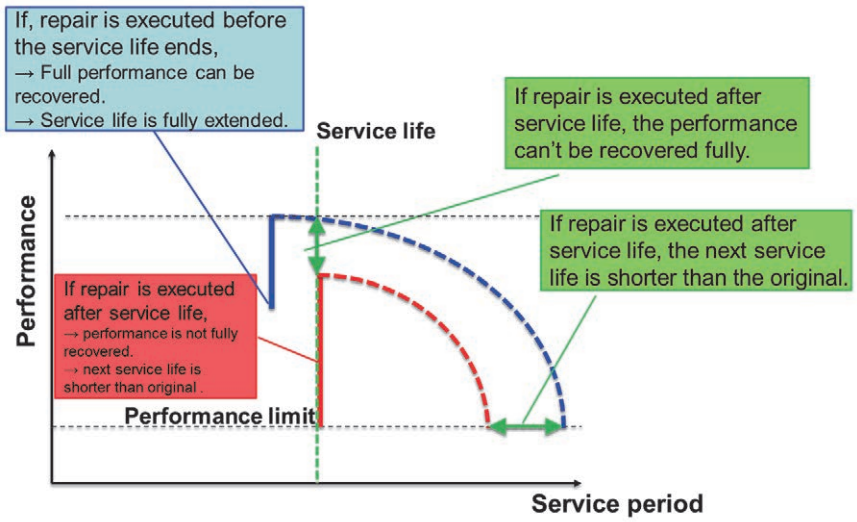


Figure 124 Image of Deterioration Curve of Concrete Structure

Case Study aims to examine measures to prolong life of RC slab and to reduce LCC of RC slab by comparing LCC of RC slab in both cases, preventive maintenance and corrective maintenance.

Definition of wording in Case Study

- Corrective maintenance here means that only deteriorated part is repaired when damage is found.
- Preventive maintenance here means that preventive measure is taken before RC slab is deteriorated.

(4) Proposed scenarios to be compared

Table 113 Proposed Scenarios to be Compared

	Corrective maintenance	Preventive maintenance
Description	Deteriorated parts of RC slabs are repaired each time.	Concrete is added over the RC slab before it deteriorates in order to strengthen and to extend its life span.
Service lLife span of RC slab	50 years (service life of concrete used in Japan)	
Maintenance cycle	1st: 50 years after construction After 2nd: Every 20 years	1st: 40 years after construction After 2nd: Every 40 years
Maintenance method	Repairing only damaged parts.	Thickening whole area of RC slab

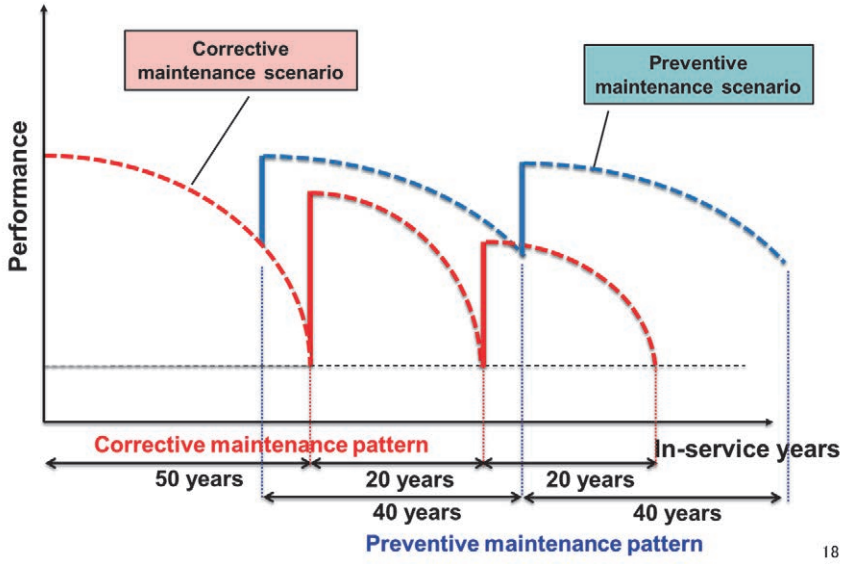


Figure 125 Image of Performance Curves by Scenario

(5) Condition for LCC analysis in corrective maintenance scenario

1) Maintenance method

i. To remove asphalt layer.

ii. To remove all damaged parts of RC slab and repairing it by RC.

iii. To lay asphalt layer on repaired RC slab.

iv. Execution of the above work 1, 2 and 3 are repeated every 20 years.

2) Dimensions to be used for examination

Table 114 Dimensions to be Used for Examination of Corrective Maintenance Scenarios

Road length	128.6 km（only elevated bridge part）
Road width	27 m (for 6 lanes)
Thickness of asphalt layer	5 or 8 cm

3) Unit construction cost

Repair unit cost of RC slab: 5,200 baht/m^2 (including costs of the above works i, ii and iii)

(6) Estimation of annual maintenance cost of RC slab by corrective maintenance

1) Estimation for Din Daeng Expressway

The estimated annual maintenance cost of RC slab for Din Daeng Expressway constructed in 1991 is shown below.

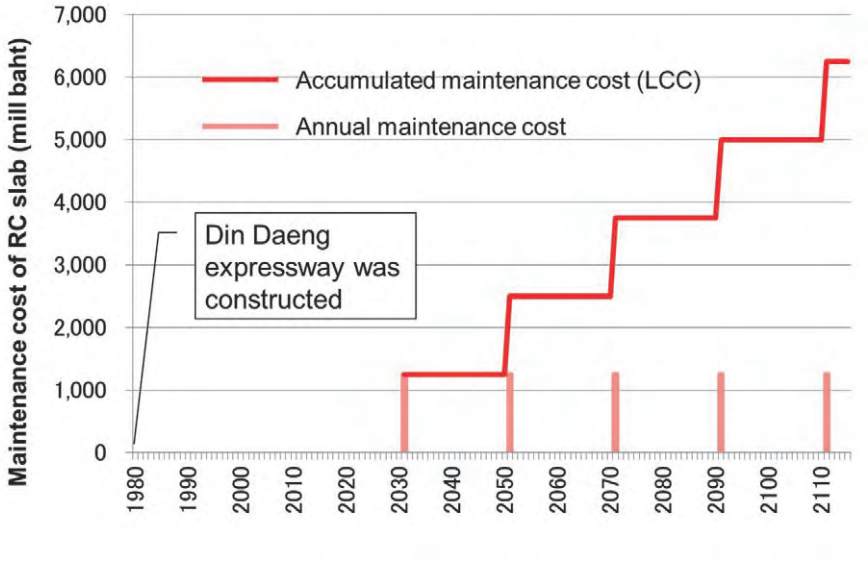


Figure 126 Accumulated maintenance cost (LCC) of RC slab by corrective maintenance for Din Daeng Expressway

2) Estimation for all expressways

The annual maintenance cost of RC slab is different by expressway route because they were constructed in the different year. Therefore, total required annual maintenance cost of RC slab is estimated.

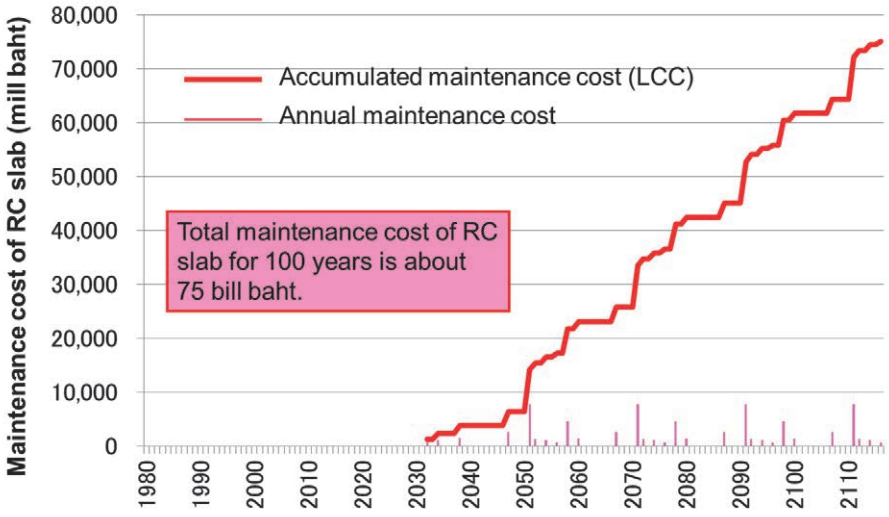


Figure 127 Accumulated maintenance cost (LCC) of RC slab by corrective maintenance for all expressways

This estimation shows that approximately 75 billion baht is required for maintenance of RC slab for 100 years from 2016 to 2115.

(7) Description of a preventive measure for RC slab to be examined

1) Name of technology

Thickening RC slab method using high durability type epoxy adhesive

2) Description

High durability type epoxy adhesive has been developed as adhesive for pouring fresh concrete on existing concrete. Conventionally in Japan, additional concrete is poured on the existing concrete as a repair method in order to recover the strength of concrete slab. However, the performance could not be fully recovered to 100% of the original strength due to weakness at the joint. This problem is solved by using high durability type epoxy adhesive.

3) Construction method

i. To remove all asphalt layer and 1 cm of the surface of RC slab.

ii. To apply epoxy adhesive on the surface of RC slab.

iii. To pour 5 cm of concrete on the RC slab.

iv. To lay asphalt layer after applying waterproof layer on RC slab

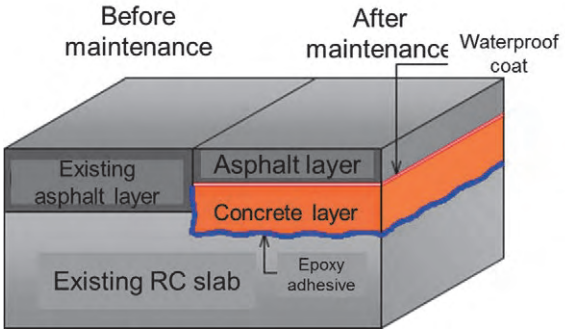


Figure 128 Image of thickening RC slab method

Figure 129 Pictures of implementation of thickening RC slab method

4) Effect by this technology

Applying high durability type epoxy adhesive improves durability, strength and water resistance of repaired RC slab and therefore prolongs the service life of asphalt pavement on RC slab.

(8) Condition for LCC analysis in preventive maintenance scenario

1) Maintenance method

Preventive maintenance can be implemented according to the schedule and, therefore, asphalt pavement work in thickening RC slab method can be implemented at the periodical overlaying work. It means that no additional asphalt overlaying work is required if the implementation timing is well coordinated.

Therefore, we examine two cases; thickening RC slab method is conducted at the periodical overlay and thickening RC slab method and periodical overlay conducted at the different period. As for corrective maintenance scenario, the implementation timing cannot be adjusted to the periodical overlay because it has to be implemented immediately after the damage is found.

Table 115 Description of Two Preventive Maintenance Scenarios

	Case 1	Case 2
Implementation timing	It is implemented without coordinating the timing of periodical asphalt overlay.	It is implemented jointly with periodical asphalt overlay.
Unit construction cost	5,600 baht/m^2	4,100 baht/m^2

2) Dimensions to be used for examination

Table 116 Dimensions to be Used for Examination of Preventive Maintenance Scenarios

Road length	128.6 km （only elevated bridge part）
Road width	27 m (for 6 lanes)
Thickness of asphalt layer	5 or 8 cm

(9) Estimated annual maintenance cost of RC slab by corrective maintenance

1) Estimation for Case 1

The estimated annual maintenance cost of RC slab for Din Daeng Expressway constructed in 1981 is shown below.

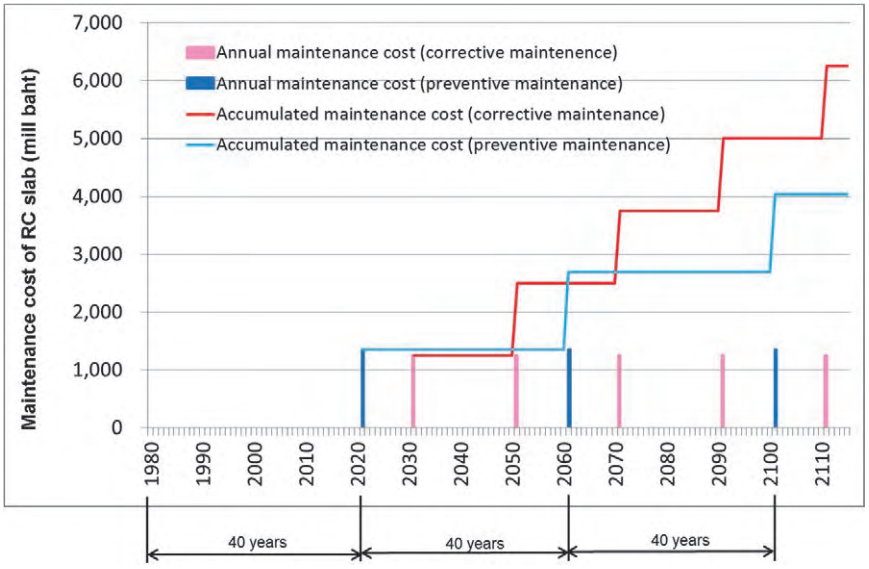


Figure 130 Accumulated maintenance cost of RC (LCC) slab for Din Daeng Expressway in Case 1

The total required annual maintenance cost of RC slab for all expressways is estimated.

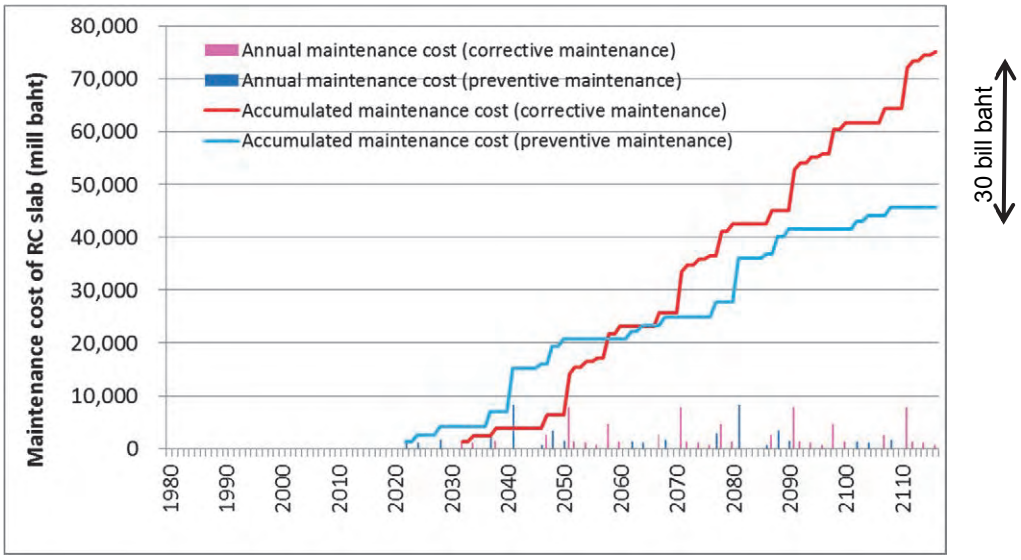


Figure 131 Accumulated maintenance cost (LCC) of RC slab for all expressways in Case 1

Although the accumulated maintenance cost by preventive maintenance is more expensive than that by corrective maintenance at the initial period, the costs reverse around 50 years later. The accumulated maintenance cost by corrective maintenance for 100 years is 75 bill baht, while the one by preventive maintenance is 45 bill baht, and thus the preventive maintenance can reduce 40% of accumulated maintenance cost in 100 years.

2) Estimation for Case 2

The estimated annual maintenance cost of RC slab for Din Daeng Expressway constructed in 1991 is shown below.

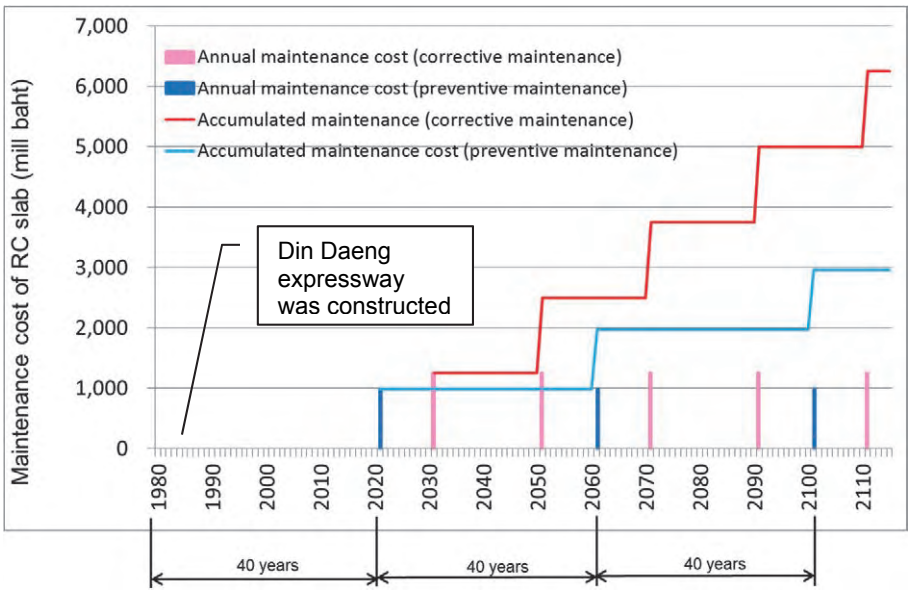


Figure 132 Accumulated maintenance cost (LCC) of RC slab for Din Daeng expressway in Case 2

This estimation shows that approximately 75 billion baht is required for maintenance of RC slab for 100 years from 2016 to 2115.

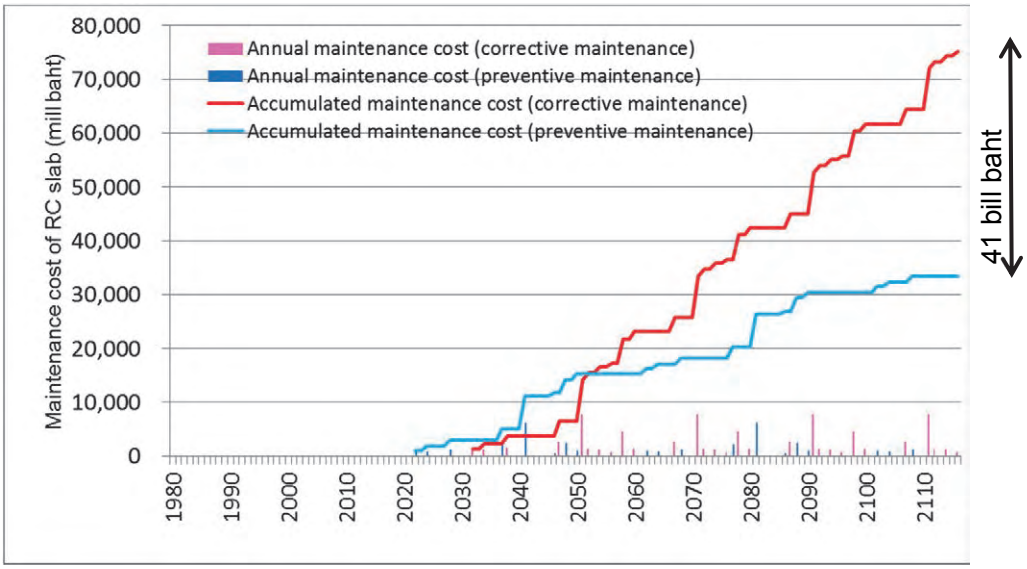


Figure 133 Accumulated maintenance cost (LCC) of RC slab for all expressway in Case 2

The accumulated maintenance cost of RC slab by preventive maintenance in Case 2 is cheaper than that in Case 1 because it does not include rehabilitation cost of road pavement. In addition, in Case 2 the costs reverses after 35 years, which is 15 years earlier than for Case 1 (reverses after 50 years).

Comparing the total maintenance costs for 100 years, it is 75 mill baht by corrective maintenance and 34 mill baht by preventive maintenance, and thus the preventive maintenance reduce 55% of total cost.

(10) Result of case study

The result of Case study is summarized in the table below.

Table 117 Result of Case Study

	Accumulated maintenance cost for 100 years (bill baht)		Cost difference	Cost reverse
	Corrective maintenance scenario	Preventive maintenance scenario		
Case 1	75	45	40%	50 years
Case 2		34	55%	35 years

(11) Impacts on maintenance cost

The required maintenance cost of RC slab by preventive maintenance in Case 1 for 100 years is 45 bill baht and it is 450 mill baht per year. If the maintenance of RC slab becomes necessary in 2013, the required maintenance budget in 2013 is 850 mill baht because the maintenance budget in 2013 excluding the maintenance budget of RC slab is 400 mill baht. In Case 2, 340 mill baht is additionally required instead of 450 mill baht in Case 1.

5.4.6 Findings

i. The long-term strategy for maintenance of concrete elevated bridge is necessary to be examined.

ii. The preventive measure should be taken for RC slab of elevated bridges in order to reduce LCC.

iii. The preventive maintenance measures for other parts than RC slab of elevated bridges should be analysed in order to reduce LCC by prolonging its useful life.

5.5 Case to Examine the Impact to LCC of Road Pavement by Doubling the Design Useful Years

5.5.1 Background and Objective

(1) Background

Since 2002, the total length of highway owned by DOH has not increased because most of new construction has been for widening existing highways. Maintenance work is increasing, while new construction of highways is decreasing, and it gradually is helping the road sector staff understand the importance of maintenance work.

At the same time, what people expect for road is being changed from accessibility to reducing traffic congestion, improvement of safety and comfort of driving, and the road sector organization starts to focus on life extension of road pavement and reduction of LCC.

Implementation of appropriate maintenance and life extension of road pavement is becoming very important.

(2) Objective

Construction and maintenance cost of asphalt pavement occupies big percentage of the expenditure for roads. Case Study compares the LCC of road based on the present design standard and LCC of road based on the longer service life design standard to find the cheaper one.

Although this case study is conducted for the pavement design standard used by DOH, the result can be applicable to the other pavement design standard used in Thailand.

5.5.2 Present Condition

In the figure, “Trend of Highway Length”, a blue line shows the actual highway length and a red line shows the highway length if there were only two lanes. This figure shows that the focus of development of highways has changed from new network construction to widening of existing highways.

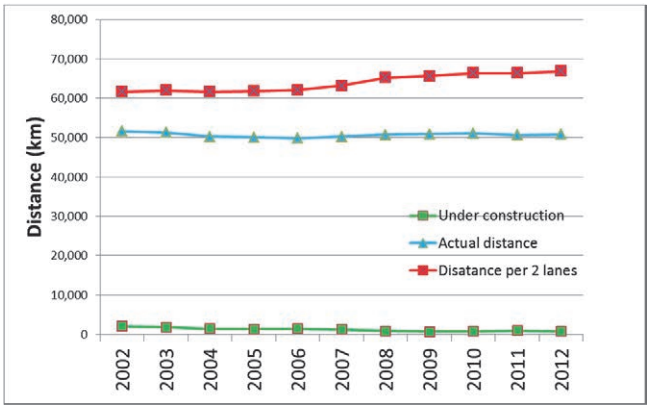


Figure 134 Length of Highway of DOH

5.5.3 Identification of Problems

It is projected that the maintenance cost will increase more in future and it will create serious financial difficulty in the road sector.

5.5.4 Setting Basic Policy

Case study adopts a reduction measure of LCC of road pavement as a basic policy and the following are potential measures to reduce LCC.

- life extension of road pavement.
- revising the design standard of road pavement.
- better maintenance by more effective utilization of PMS.

These three measures have been taken in Japan, and the revision of design standard for road pavement introduced in 2001, which recommends to adopt the longer road pavement design period such as for 20 years without following the former design period for 10 years, has greatly encouraged national and local authorities to adopt the longer life road pavement design. This has considerably contributed to reduce LCC of road pavement.

Therefore, Case Study examines the impact to the LCC of road pavement by the revision of road pavement design standard in Thailand.

5.5.5 Methodology of Examining Countermeasures

(1) Proposed alternative

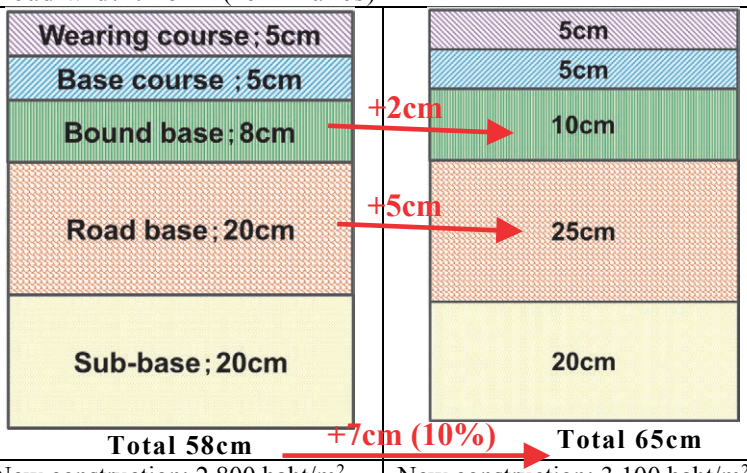
Based on the road pavement design standard of DOH as an example, the alternative to be compared is proposed for 30 years design period.

Table 118 Basic Policy of Examining Countermeasures

Design standard	Design period	Remarks
Present design period	15 years	Present design period
Long life design	30 years	Twice of present design period

(2) Conditions for Case study

Table 119 Conditions for Case Study

	Present design	Long life design
Period for road pavement design※1	15 years	30 years
Design method	Ta method※2	
Design CBR※3	Average 4%	
Useful life of road pavement※4	15 y + 5 = 20 years	30 y + 5 = 35 years
Rehabilitation interval	20 years	35 years
Unit of road	Traffic volume: 50,000 vehicle per day Road length: 1 km Road width: 15 m (for 4 lanes)	
Road pavement structure※5		
Unit construction cost※6	New construction: 2,800 baht/m^2 Rehabilitation: 2,450 baht/m^2	New construction: 3,100 baht/m^2 Rehabilitation: 2,750 baht/m^2

※1 Period for road pavement design means that the period until cracks appear on road pavement by repeated wheel loads.

※2 Design method for road pavement design method used in Thailand and also in Japan.

※3 Index for the strength of road base.

※4 The actual useful life of road pavement in Thailand is said to be around 15 to 25 years, 20 years on average, and therefore the actual useful life is set by adding 5 years to the design service life.

※5 The pavement structure was determined based on TA method, 50,000 vehicle per day and for 30 year service life.

※6 New road pavement construction cost shall include asphalt pavement and road base. Road pavement rehabilitation cost includes the same cost as new construction cost and removal and disposal cost of the former road pavement.

(3) Result of Analysis

Based on the conditions, the new construction and maintenance cost of road pavement required for 100 years is estimated.

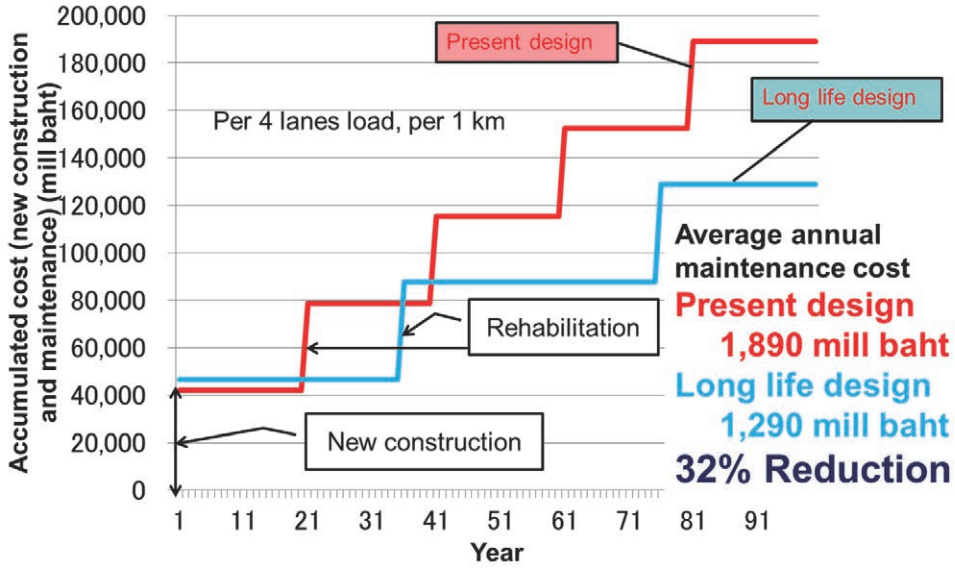


Figure 135 Estimated LCC of Road Pavement by Different Design Useful Life

Although the initial construction cost of road pavement based on 30 years service life design is more expensive than that based on 15 years service life design, LCC based on 30 years service life design get cheaper due to the longer service life. The result of comparison of LCCs based on the different design useful life is described below.

LCC for 100 years divided by 100 years

- 15 year service life design: 1,890 thousand baht/year
- 30 year service life design: 1,290 thousand baht
- LCC based on 30 year service life design is cheaper by 32%.

LCC per one service life divided by service life

- 15 year service life design: 2,100 thousand baht (42 mill. baht divided by 20 years)
- 30 year service life design: 1,328 thousand baht (46.5 mill. baht divided by 35 years)
- LCC based on 30 year service life design is cheaper by 37%.

(4) Summary of Case Study

The results of the Case Study are summarized in the following table. LCC of road pavement can be reduced by 32% based on 100 years and also by 37% based on one service life by the revision of the road pavement design standard.

Table 120 Result of Case Study

		Present design	Long life design	Difference
Period for design		15 years	30 years	**2 times**
Total thickness of pavement		58cm	65cm	**+10%**
Unit construction cost		New construction: **2,800 baht/m2** Rehabilitation: **2,450 baht/m2**	New construction: **3,100 baht/m2** Rehabilitation: **2,750 baht/m2**	**+10%**
Annual average cost	Case 1	1,890 bill baht/year	1,290 bill baht/year	**-32%**
	Case 2	2,100 bill baht/year	1,328 bill baht/year	**-37%**

5.5.6 Findings

1) Reduction of LCC of road pavement by revising the road pavement design standard

Revising the road pavement design standard to enable adoption of life extension technologies to the road design helps to reduce LCC of road.

2) To properly select a suitable technology depending on the site condition and its purpose

Because each life extension technology has various advantages and disadvantages depending on various conditions such as ground condition, traffic volume, etc., it is effective to select a suitable technology depending on the site condition and its purpose. If unsuitable technology is selected, the service life of road pavement becomes even shorter. Such life extension technologies can be adopted not only in new construction but also in road rehabilitation.

Table 121 Long Life Pavement Main Technologies

	Crossing	Heavy traffic road	Firm ground
Polymer modified asphalt	Suitable	Suitable	Suitable
Composite pavement	Unsuitable	Unsuitable	Suitable
SMA pavement	Suitable	Suitable	Suitable

3) To utilize Pavement Management System fully for the long term maintenance plan

PMS which is used by both DOH and DRR is an effective tool to consider the long-term strategy for road maintenance. To fully use PMS for long-term strategy helps to reduce LCC of roads.

6 Technical Transfer

6.1 Workshop

For the purpose of explaining study objectives and introducing the approaches toward infrastructure management in Japan, a workshop was held on July 16th with the attendance of invitees from target organizations related to infrastructure management. There were 59 participants from 16 target organizations and one university, as listed in Table 122. [71] As a rule, up to three persons were to be accepted from each organization, but some organizations requested participation of four or more of their staff. This is evidence of the high need for technical improvement of infrastructure management. From the results of the post-workshop questionnaires, it was found that the power sector had a particularly high interest in this issue because all the participants from the power sector filled out the questionnaire.

Table 122 The Number of Participants by Organization

No.	Organization	Participants
1	Bureau of the Budget (BOB)	3
2	Fiscal Policy Office (FPO)	3
3	State Enterprise Policy Office (SEPO)	3
4	National Economic and Social Development Board (NESDB)	3
5	Bangkok Metropolitan Administration (BMA)	6
6	Department of Public Works and Town & Country Planning (DPT)	3
7	Department of Highways (DOH)	2
8	Department of Rural Roads (DRR)	3
9	Expressway Authority of Thailand (EXAT)	4
10	State Railway of Thailand (SRT)	3
11	Mass Rapid Transit Authority of Thailand (MRTA)	3
12	Metropolitan Electricity Authority (MEA)	3
13	Provincial Electricity Authority (PEA)	5
14	Electricity Generating Authority of Thailand (EGAT)	4
15	Metropolitan Waterworks Authority (MWA)	3
16	Provincial Waterworks Authority (PWA)	4
17	Chulalongkorn University	4
	Total	59

The answers to the questionnaires revealed that the workshop enhanced the awareness of infrastructure management with a focus on preventive maintenance and that there were needs among the participants for Japanese technology and knowledge for all the aspects of infrastructure management. There were favorable responses in the questionnaires regarding

[71] Chulalongkorn University applied for workshop participation through PEA, which had a plan to carry out a joint project with the university.

the introduction of the concept of infrastructure management and the introduction of Japanese technology and knowledge on infrastructure management, both of which were the objectives of the study.

6.1.1 Outline of the Workshop

The program of the workshop and summary of discussions by the participants are given below. The presentation materials can be found in the appendix of this report.

Schedule of the Workshop

Title: Workshop on Infrastructure Management in Thailand
Date: July 16th (Wednesday), 2014 from 10:00-12:20 pm
Venue: HOTEL NOVOTEL BANGKOK ON SIAM SQUARE
Siam Square Soi 6, Pathumwan,

Time	Programme
9:30-10:00	Registration
10:00-10:10	Opening remarks Representative of JICA Thailand Office
10:10-10:20	Objective of the study and Workshop Mr. Akira Doi, Team leader
10:20-10:30	Key note speech "Growing needs of managing aging infrastructure facilities in Thailand" Advisor, Dr. Worsak Kanok-Nukulchai, Interim President, AIT
10:30-10:45	1. Political approaches to extended life of infrastructure facilities Ms. Junko Tomita, Financial planning expert
10:45-10:55	2. Overview of infrastructure management Mr. Akira Doi, Team leader
10:55-11:15	3. Infrastructure management in Japan - Roads and bridges Mr. Akira Doi, Team leader
11:15-11:25	4. Infrastructure management in Japan - Water supply facilities Mr. Kenji Shinoda, Water supply planning expert
11:25-11:32	5. Infrastructure management in Japan - Sewerage facilities Mr. Kenji Shinoda, Water supply planning expert
11:32-11:42	6. Technologies for infrastructure management Mr. Akira Doi, Team leader
11:42-11:45	7. Summary of presentation Mr. Akira Doi, Team leader
11:45-12:15	Discussion Mr. Makoto Ashino, Traffic and transport planning expert
12:15-12:20	Closing remarks Mr. Akira Doi, Team leader
12:20-	Lunch

Discussion Summary

Department of Highways, Ministry of Transport (DOH)

The main issue of infrastructure management is how to secure and develop the human resources for the future. The number of engineers is sufficient, but IT specialists are in short supply resulting in delayed responses to server breakdowns and system maintenance.

We will need to introduce a new IT system and to carry out a project aiming at long-term facility maintenance. There are few organizations in Thailand that practice the concept of infrastructure maintenance from a comprehensive and long-term point of view.

Bureau of Budget, Office of Prime Minister

Thailand's total national budget is not sufficient. 70% of the budget is regular budget and loans of 2 trillion baht a year are needed for investment.

The bureau understands the necessity of improving existing infrastructure, but it poses a great financial burden. Because it also needs to set aside budget for investment projects, infrastructure management initiatives will not be feasible in the immediate future. It is obvious that breakdown maintenance is inefficient and can entail excessive costs; however the national budget is limited. Therefore, currently each organization is addressing the issues independently. There is an expectation of sound assistance from JICA.

Electricity Generating Authority of Thailand (EGAT)

With regard to infrastructure management Thailand is still in the development stages and is currently applying laws and regulations with reference to those in Japan and the USA. In accordance with the changes of the times, laws and regulations must be thoroughly reviewed, with particular emphasis on public safety and health, and drastic measures should be taken.

Provincial Electricity Authority (PEA)

The internal discussions within PEA are currently underway about asset management. PEA understands and recognizes the significance of the concept of preventive maintenance. The power transmission grid is obsolete as it is already 40 to 50 years old.

The total assets of PEA are about 300 billion baht, or 200 billion baht if buildings are excluded. Breakdown maintenance has been its primary form of maintenance. It is currently in the process of making the change from PAS55:2008 to ISO55001. Currently, however, there are no clear criteria to determine the necessity of repairs or replacement (upgrading) as PEA has no asset management guidelines. Areas where PEA needs to focus its resources in the future are: human resources development, technology improvement, legislation amendment, guidelines formulation and database development. Furthermore, strengthening of asset management and preparation of a roadmap are also necessary.

6.1.2 Feedback from Participants

The questionnaires were distributed to the workshop participants and answers were collected from 39 persons. The questionnaire focused on the following four areas.

1) Topics (lectures) that were of the most interest
2) Problems with infrastructure facilities
3) Suggested solutions to the problems
4) Comments about the presentations and discussions

The analysis results of the replies are described below in order.

Interesting Topics

Overall, commonly applicable topics to all the sectors such as "1. Political approaches to extend life of infrastructure facilities", "Overview of infrastructure management" and "Technologies for infrastructure management" were interesting for most participants and appreciated regardless of sector, as shown in the following figure. Ideas such as comprehensive and careful long-term planning and preventive maintenance rather than breakdown maintenance attracted attention as they seemed to be new to the participants. The presentation "Technologies for infrastructure management" attracted special attention not only because the slides were easy to follow with a number of photos but also because advanced technology for effective data collection and management stimulated the interest of the participants who are in the process of developing a system for infrastructure management.

Topics on road, water supply and wastewater sectors garnered interest both from sector insiders as well as those in policy and finance sectors. It showed that the organizations in charge of national policy, long-term planning and budgetary control had strong interests in infrastructure sector and its efficient operation and management.

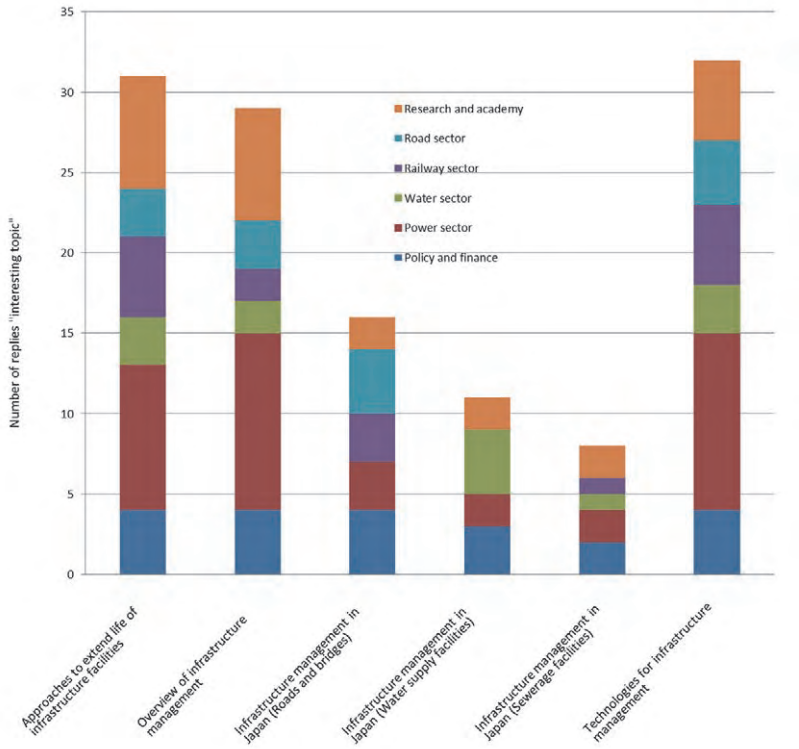


Figure 136 Interesting Topics by Sector (multiple answers allowed)

Source: Result of workshop questionnaire

Problems with Infrastructure Facilities

Most of the participants raised the problem of budget shortages. Bureau of Budget seemed to recognize this problem most strongly, followed by the other sectors including power, railways, roads and water which pointed out the problems of a lack of budget and budget management capacity. NESDB pointed to potential obstacles anticipated in attempting to undertake preventive maintenance such as shortage of human resources, budget and technology.

IT related issues were also outstanding. For example, BMA commented that the database, which should be a prerequisite for preventive maintenance, was not yet established. The power and water sectors stated that their databases were not regularly updated. DOH pointed out a lack of IT specialists. Insufficient technology or engineers and inadequate management institutions were found to be common problems to all sectors.

The workshop fulfilled its purpose since it reminded the participating organizations of their desire for preventive maintenance and problems to be solved. Meanwhile, it was clearly understood that fundamental issues such as budget, human resources, technology and management systems were unavoidable for infrastructure management.

Solutions to the Problems

Bureau of Budget stated that the national budget was not enough to cover operation and maintenance since the country predominantly required new investment, and that it would allocate budget in an efficient manner. However, it did not mention any further details. The power sector proposed to collaboratively develop inter-sectorial management policies. There were also requests to JICA and other donor agencies for financial assistance, technical support regarding technologies introduced in the workshop and opportunities of human resource development by overseas training. All the sectors were found to have strong needs for new types of human resources required for preventive maintenance.

Comments about the Presentations and Discussions

The State Enterprise Policy Office (SEPO), which is the authority in charge of PPPs in Thailand, showed an interest in the application of PPPs in infrastructure management and requested practical knowledge in regard to Japanese legal frameworks, as Thailand has a policy to utilize PPPs.

Requests from the participants included the introduction of practical examples of preventive maintenance of the power and railway sectors, sharing of the Japanese experience of transition to preventive maintenance and transfer of preventive maintenance methodologies. For example, the power sector expressed its desire to know the operation and maintenance techniques applied by Tokyo Electric Power Company.

The participants showed clear expectations for the provision of technology and know-how for entire aspects of infrastructure operation and maintenance including PPPs.

6.2 Seminar

For the purpose of explaining the results of the study and suggestions regarding asset management, a seminar was held on October 21st with the attendance of invitees from target organizations related to infrastructure management. There were 60 participants from 17 target organizations and one university.

Table 123 The Number of Participants by Organization

No.	Organization	Participants
1	Bureau of the Budget	5
2	Fiscal Policy Office (FPO)	3
3	State Enterprise Policy Office (SEPO)	2
4	Public Debt Management Office (PDMO)	3
5	National Economic and Social Development Board (NESDB)	3
6	Department of Public Works and Town & Country Planning (DPT)	2
7	Department of Highways (DOH)	3
8	Department of Rural Roads (DRR)	3
9	Expressway Authority of Thailand (EXAT)	3
10	State Railway of Thailand (SRT)	5
11	Mass Rapid Transit Authority of Thailand (MRTA)	4
12	Metropolitan Electricity Authority (MEA)	5
13	Provincial Electricity Authority (PEA)	2
14	Electricity Generating Authority of Thailand (EGAT)	3
15	Metropolitan Waterworks Authority (MWA)	6
16	Provincial Waterworks Authority (PWA)	4
17	Wastewater Management Authority (WMA)	1
18	Chulalongkorn University	3
	Total	60

6.2.1 Outline of the Seminar

The program of the seminar and summary of discussions by the participants are given below. The Study Team presented the infrastructure management situations analyzed through this study and three case studies to show the effect of life extension measures using life-cycle cost in water and road sectors. There was a presentation from a professor in Chulalongkorn University about ISO55000, which is the International Standard of asset management. The Study Team Leader summarized the key points for successful infrastructure management.

The presentation materials can be found in the appendix of this report.

Schedule of the Seminar

Title: Workshop on Infrastructure Management in Thailand
Date: October 21st (Tuesday), 2014 from 10:00-12:30 pm
Venue: HOTEL NOVOTEL BANGKOK ON SIAM SQUARE
Siam Square Soi 6, Pathumwan,

Time	Programme
9:30-10:00	Registration
10:00-10:10	Opening Remarks Mr. Shuichi Ikeda, Chief Representative of JICA Thailand Office
10:10-10:20	1. Progress of the Study and the Objective of Seminar Mr. Akira Doi, Team Leader
10:20-10:35	2. Issues Related to Infrastructure Management in Thailand Ms. Junko Tomita, Financial Planning Expert
10:35-10:50	3. Key Points in Infrastructure Management Mr. Akira Doi, Team Leader
10:50-11:10	4. Case Study for Water Supply Facility Mr. Kenji Shinoda, Water Supply Expert
11:10-11:25	5. Case Study for Concrete Structure Mr. Hideo Sato, Infrastructure Management Expert
11:25-11:40	6. Case Study for Road Pavement Mr. Hideo Sato, Infrastructure Management Expert
11:40-11:55	7. ISO 55000 Asset Management System Assoc. Prof. Suthas Ratanakuakangwan, Chulalongkorn University
11:55-12:00	8. Wrap up the Seminar Mr. Akira Doi, Team Leader
12:00-12:30	Discussion Mr. Makoto Ashino, Traffic and Transport Expert
12:30-12:35	Closing Remarks Mr. Akira Doi, Team Leader

Discussion Summary

Because of shortage in time, there were two comments.

Provincial Electricity Authority (PEA)

ISO55000 intends to upgrade the organization by visualizing efficient business operation by balancing cost, invisible risk and performance. PEA believes that obtaining ISO certification is meaningful because it can enhance user confidence.

Department of Highways (DOH)

We understand the importance of revising standards to actually utilize new technologies for life extension. However, it is not easy to promote improvement partly because the Budget Bureau uses its implicit knowledge of unit cost of road pavement.

Accumulation of data based on test execution is required to convince the related parties to revise the standards. We expect Japan's support for this.

6.2.2 Feedback from Participants

The questionnaires were distributed to the workshop participants and answers were collected from 30 persons. The questionnaire focused on the following four areas.

1) Topics (lectures) that were of the most interest
2) Importance of key messages
3) Difficulties and obstacles to accomplish organization's roles for infrastructure management
4) Comments about the presentations and discussions

The analysis results of the replies are described below in order.

Interesting Topics

The number of participantes whoresponded the topic inteteresting by topic were shown in the following table. Each case study was interesting for about one third of participants because it might require high professional knowledge to understand. However, participants from not only road and water sectors but also other sectors were interested in case studies. On the other hand, general topics on infrastracture management are interesteing for about two thirds of participants.

Table 124 Number of Responses to be Interesting by Topic

Topic	Responses
Issues Related to Infrastructure Management in Thailand	21
Key Points in Infrastructure Management	19
Case Study for Water Supply Facility	12
Case Study for Concrete Structure	13
Case Study for Road Pavement	11
ISO55000 Asset Management System	19

Importance of key messages

As the summary of this seminar, we pointed out keys to implement infrastructure management we found through this study. The questionnaire asked how important the participants consider for each key message. The following graph summarizes how many participants consider how important by message.

Table 125 Key Messages Important for Infrastructure Management

Message number	Key Message
1	Infrastructure management is a key tool for the policy change from "construction" to "use".
2	Utilization of LCC analysis is essential to select an optimal and minimum cost measures
3	Treat before damaged to keep LCC as minimum
4	Procurement based on LCC is a key to have good things with minimum cost in the long run
5	Design standard should consider more LCC
6	Expensive technologies to extend life should be used only inevitable part. More detailed design is required to attain the minimum cost.
7	Plans in infrastructure management should be adjusted periodically using inspection result. That is PDCA.

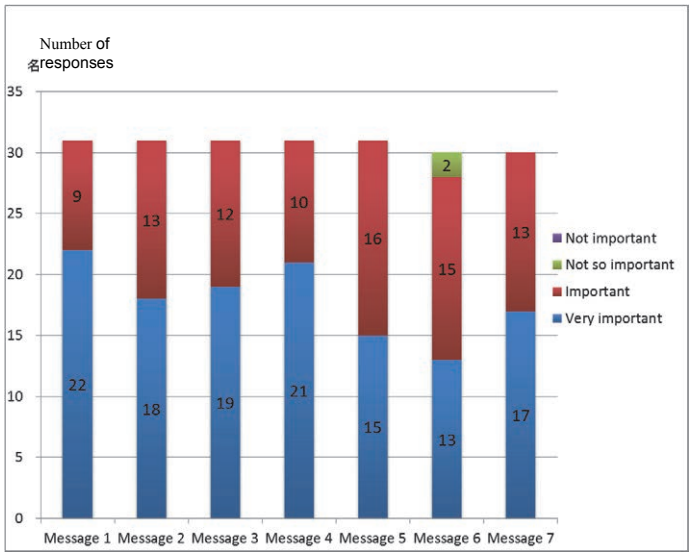


Figure 137 Recognition of Importance by Key Message

Participants understand the importance of all messages, especially importance of infrastructure management and use of LCC for procurement are understood well.

Solutions to the Problems

Bureau of Budget stated that the national budget was not enough to cover operation and maintenance since the country predominantly required new investment, and that it would allocate budget in an efficient manner. However, it did not mention any further details. The power sector proposed to collaboratively develop inter-sectorial management policies. There were also requests to JICA and other donor agencies for financial assistance, technical support regarding technologies introduced in the workshop and opportunities of human resource development by overseas training. All the sectors were found to have strong needs for new types of human resources required for preventive maintenance.

Difficulties and obstacles to accomplish organization's roles for infrastructure management

Participants from implementation organizations recognize laws and rules, policy, and budget as obstacles. Other issues mentioned are that it is difficult to convince budget bureau and executives and especially because they do not have proven performance to convince, and that structural separation between planning and maintenance makes difficult to share information.

Comments about the Presentations and Discussions

Participants understand the importance of systematic effort for infrastructure management and request case studies in railway and electricity sectors as well.

Overall, participants recognize issues in the current maintenance and repair style and needs for implementing infrastructure management based on a long-term perspective.

7 Findings from the Survey

Taking the present condition of infrastructure management and relevant organization's needs, the suggested measures are examined in terms of following five aspects.

1) Financial source
2) Management policy and needs
3) Management plan and measures
4) Organization structure and skills
5) Support from Japan

7.1 Financial Source

7.1.1 Utilization of PPP/PFI

SEPO is active in introducing private funds such as PPP schemes and infrastructure funds for the development and operation of infrastructure which can be expected to return a profit. Regarding the organizations such as EXAT which can obtain stable revenue, SEPO plans to adopt concession type contracts covering both operations and maintenance. In addition, SEPO has a plan to apply PPP contract for MWA as well.

7.1.2 Securing funding for Maintenance

Securing funding is essential to continue steady maintenance of existing infrastructure facilities. Japan raised road-use taxes legislated for road construction based on beneficiaries-pay principle and part of maintenance was financed from these taxes. It is an effective way to create taxes and subsidies preferentially allocated for maintenance activities in Thailand.

7.2 Management policy and needs

7.2.1 Creation of Framework for Infrastructure Management

In Thailand there is a continuing demand for new infrastructure construction and infrastructure facilities are increasing and aging at the same time. Under such a circumstance, issues of how to support budget for new investment and maintenance at the same time bear down on the government. The following are suggested as a solution.

3) For new construction, consider measures to minimize LCC from design, procurement through to the end of use.
4) For maintenance of existing infrastructure facilities, consider LCC and implement measures against aging and for life extension

To promote proactive engagement in this policy to implementing organizations, it is effective that national competent authorities set a holistic policy for implementing

organizations at national and local levels to consider all infrastructure facilities including both new and existing infrastructure facilities.

Currently as shown in Figure 138, maintenance divisions in implementing organizations are successfully trying every effort to improve practical maintenance operations such as inspection, data management. However, laws and rules, design standard, and policies of implementing organizations sometimes interfere with further improvement.

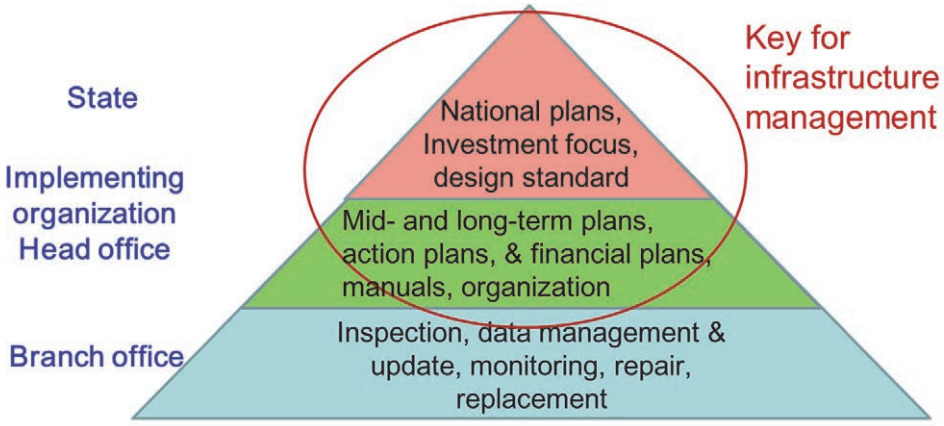


Figure 138 Issues in Infrastructure Management in Thailand

The same issues are also seen in Japan. Then the Japanese central government formulated holistic policy to consider management of both new and existing infrastructure facilities by establishing three upper level plan, namely, Basic plan to extend life of infrastructure facilities, Action plan to extend life of infrastructure facilities, and comprehensive public facility management plan. Such an approach is also effective for Thailand to satisfy both needs for new construction and maintenance of existing infrastructure facilities.

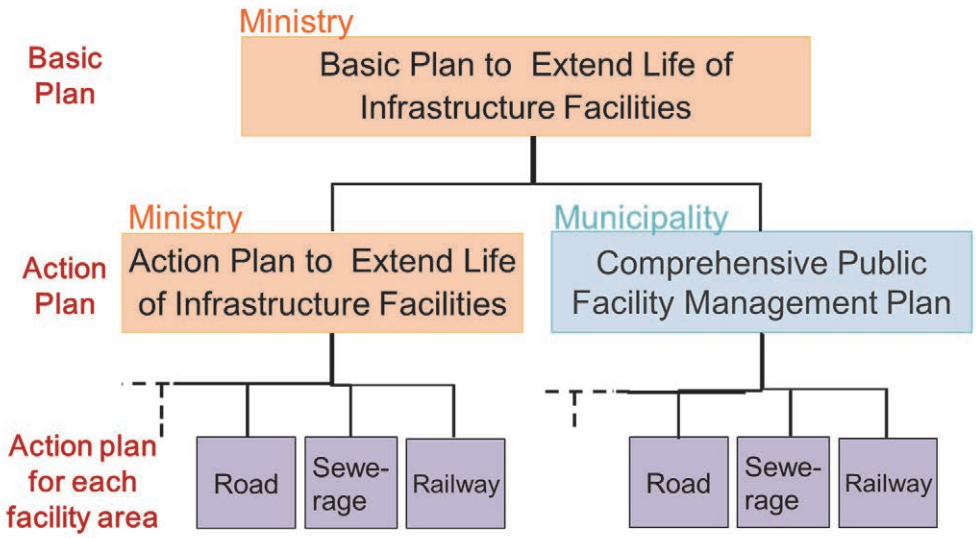


Figure 139 Government-led Plan to Extend Life of Infrastructure Facilities

7.2.2 Approaches to State Own Enterprises

Since run on a stand-alone basis, state own enterprises recognize infrastructure facilities as essential asset to generate profits and they possess the basic mechanisms for undertaking optimal maintenance measures. They have the right in its sole discretion to decide mostly on budget allocation for new investment and maintenance. In case a profitable state own enterprise takes inadequate asset management measures, it is attributable to its knowledge and capacity. They have pretty good chance of improvement.

The most effective means for influencing state own enterprises' business policy is Statement of Directions made by NESDB, Office of Prime Minister, and SEPO every year. Statement of Directions shows policies for five-year and one-year for every state own enterprises. All state own enterprises make their five-year plan and annual investment plan. Especially Statement of Directions for waterworks sector includes consideration of asset management. Therefore, specification in Statement of Directions is an influential way to stimulate state own enterprises to promote asset management.

7.3 Management plan and measures

7.3.1 Road Sector

1) Integrated management is essential for successful asset management and organization structures enabling cross-sectional and comprehensive consideration and decision making works well.

2) Pavement

   - Reduction of LCC by life extension is an important method and it is effective to proactively promote research on life extension technology and data accumulation on a trial basis.
   - In order to maximize the advantage of life extension technologies, research should be undertaken to find best uses of materials and detailed design.

3) RC structures

   - Understanding of the current situation of RC structures is urgent, therefore, inspection work and the preparation of inspection database of all facilities should be completed as soon as possible.
   - It is necessary to promote research on various life extension technologies and data accumulation by trial construction to prepare for the future deterioration of RC structures.

7.3.2 Waterworks

1) The case study showed advantage of consideration of LCC in selection of several technologies and materials and of planning a long-term strategy based on cost estimation for longer than the service lives of materials and equipment. The cost

estimation in the case study is based on many assumptions, and by using this as a guide for estimation, more accurate and reliable consideration based on actual data is required.

2) This case study implied that mixed use of materials considering the environmental conditions contributes to improvement of maintenance through a cost estimation of PVC pipe, HDPE, and DIP. MWA should continue consideration of materials and proactively find and use new and better materials.

7.4 Organization structure and skills

7.4.1 Road Sector

1) DOH and DRR offer staff training on maintenance including practical works and LCC method. It is useful and should be continued.

2) In Japan revision of design standards of pavement in 2001 promoted life extension of new pavement and use of life extension technologies for maintenance, which contributed to cost saving of maintenance costs. In Thailand, it can be beneficial that DOH, DRR, EXAT and MOT examine such revision.

7.4.2 Waterworks Sector

1) The integrated management of infrastructure facilities is essential for successful asset management. Especially for waterworks, better selection of pipelines can save water production costs and the required capacity for water purification facilities. Even larger investment for maintenance can contribute to reduction of operation costs and cost saving as a whole. Such a decision can be made based on a cross-sectional perspective, and therefore it is effective to establish an organizational structure that enables cross sectional considerations and decision making.

2) Each of PWA's 233 branch offices procures materials independently, which is inefficient and leads to large stock beyond necessity. Procurement costs can be saved drastically if PWA headquarters establish joint warehouses in several places nationwide and jointly procure and store materials there until each branch office comes to pick up necessary quantities.

7.5 Support from Japan

7.5.1 ODA

(1) Road sector

Training focusing on infrastructure management is an effective contribution.

1. Name of training: Infrastructure Management for Road Sector	
2. Objectives A) To learn a series of maintenance works such as inspection, data analysis, repair, etc. B) To learn theory of LCC and projection of deterioration curve C) To learn comprehensive and long term approach of infrastructure management D) To learn outsourcing and PPP techniques E) To learn technologies of life extension F) PDCA management cycle and ISO55000 as infrastructure management technique	
3. Main program	
Category	Subject
1) Issues of road facilities maintenance	● The impact to infrastructure facilities by the change of social condition in Japan, Europe and USA.
2) Maintenance and replacement of aging road facilities	● Examples of accidents of infrastructure facilities. ● Recent tends of infrastructure facility management.
3) Maintenance technologies for structures	● Inspection, repair, reinforcement.
4) Miscellaneous of road (signboards, lighting, etc.)	● Inspection, examples of damages, repair, reinforcement.
5) Bridges	● Inspection, examples of damages, repair, reinforcement. ● Utilization techniques of BMS.
6) Maintenance of earth structure	● Inspection, examples of damages, repair, reinforcement.
7) Management and maintenance of road pavement	● Road surface condition survey, analysis of road surface condition data. ● Utilization of PMS. ● Projection of deterioration curve of road pavement. ● Life extension technologies. ● Long life design.
8) IT technologies for road maintenance	● Inspection, database, data transfer.
9) Infrastructure management	● Maintenance management. ● Asset management. ● Infrastructure management.
10) Life extension method	● LCC analysis. ● Projection of deterioration curve. ● Life extension technologies. ● Life extension plan.
11) Management method	● PDCA management cycle. ● ISO55000. ● Outsourcing, comprehensive outsourcing, PPP.

(2) Waterworks sector

Training focusing on infrastructure management is an effective contribution.

1. Name of training: Infrastructure Management for Waterworks	
2. Objectives A) Management of waterworks B) To learn a series of maintenance works such as inspection, data analysis, repair, etc. C) To learn theory of LCC and projection of deterioration curve D) To learn comprehensive and long term approach of infrastructure management E) To learn outsourcing and PPP techniques F) To learn technologies of life extension G) PDCA management cycle and ISO55000 as infrastructure management technique	
3. Main program	
Category	Subject
1) Maintenance condition of waterworks operation	● The impact to waterworks sector by the change of social condition in Japan, Europe and USA. ● Examples of accidents of waterworks facilities. ● Recent tends of waterworks management.
2) Maintenance of pipelines for distribution and supply	● Advantages, disadvantages and LCC of each type of pipe.
3) Operation and maintenance of water purification plant	● Inspection, examples of damages, repair, reinforcement. ● LCC of equipment and materials
4) Water leakage management	● Identification method of water leakage area by water balance analysis using flowmeter. ● Utilization of water leakage detector, fiber scope camera, etc.
5) IT technologies for waterworks management	● Inspection, database, data transfer. ● Utilization method of GIS map.
6) Infrastructure management	● Maintenance management. ● Asset management. ● Infrastructure management.
7) Life extension method	● LCC analysis. ● Projection of deterioration curve. ● Life extension technologies. ● Life extension plan.
8) Management method	● PDCA management cycle. ● ISO55000. ● Outsourcing, comprehensive outsourcing, PPP.

7.5.2 Utilization of Japan's Technologies and Know-Hows

(1) Road Pavement

1) Inspection and database

Both DOH and DRR regularly conduct road surface condition surveys using road surface survey vehicles since around 2005, where inspection data are stored in database and analyzed in system. DOH uses Thai Pavement Management System (TPMS) based on HDM-4 recommended by the World Bank. DRR uses PMMS (Pavement Maintenance

Management System) based on Rosy recommended by ADB. Rosy was developed in collaboration with Chularongkorn University, which is a leader of various tasks related to Rosy (or: road maintenance management systems), has accumulated its own inspection data and maintains a strong position in this field. BMA is a somewhat behind in this regard, and is currently developing a pavement management system. Under such circumstances, it will be difficult to enter into this market.

2) Life extension technologies

Modified asphalt pavement is widely used in Thailand and contractors in Thailand have skills enough to work without problems. Composite pavement is used on a trial basis not to extend life but to enhance durability on soft ground. The surface was cracked soon, and it was firmly believed as an inappropriate technology. There are also problems that it is difficult to obtain aggregate suitable for composite pavement and it is more expensive than ordinary pavement. As such, it will be difficult to introduce composite pavement, and the chances are that it is used for bare minimum parts.

Draining pavement is not used in Thailand. It will be beneficial to use in rainy Thailand for the reduction in accidents on rainy days. However, considering the problems with clogging on the surface with dust during the dry season and difficulty in obtaining suitable aggregate, it will be difficult to introduce this pavement in Thailand.

DOH already applies SMA pavement at intersections and other parts requiring durability as a trial basis. It receives good recognition and if recognized as a good way of life extension, it can be widely used.

3) Maintenance of ancillary facilities using GIS

GIS is widely used for maintenance of ancillary facilities on roads such as sign posts, guard rails, light polls, and plants in Japan in accordance with the development of MMS which contributes to cost reduction of measurement work. GIS is not used in such a way in Thailand yet because there is no map for base and no needs for management using GIS. Under such circumstances, a Japanese small measurement company opened a branch in Thailand aiming for market entry, however, it will be difficult to create demand for this kind of service.

(2) Bridges and RC structures

1) Inspection and database

DOH and DRR own approximately 23,000 RC structures. Both have Bridge Management Systems (BMS), but they are waiting for data, as the progress of inspection work for data accumulation is delayed due to shortage in budget and skilled engineers. Inspection work itself is mainly based on visual checks and data input is done on the spot through tablet computer. As such the system is already equipped well.

Kansai Construction Survey Co., Ltd. conducted a feasibility study of its crack measuring system with financial assistance from JICA 2013. According to its interview with the infrastructure management business operators, their needs for acquiring accurate data are low.

There is a possible market, albeit a small one, for concrete soundness diagnosis portable kits because BMA has already bought similar equipment, and for structure inspection camera "DS Camera" system because DOH is interested in installing some in future.

There can be a possibility to install a state-of-the-art technology such as automatic variability measurement system for bridges, which is under development in Japan, because Thailand has several long bridges which are very difficult to inspect but very important.

2) Concrete repair technologies

BMA already uses water repellent agent and carbon fiber sheet for repair of concrete of their many deteriorated bridges. However, other organizations do not have so many deteriorated bridges and they do not use such technologies yet. In future as bridges become old and such needs increase, more organizations may use such new technologies.

Especially for expressways of EXAT, there may be needs for thickening RC slab method which was introduced in the case study, but that will most likely not be until 2020 or later.

(3) Waterworks

1) Inspection and database

MWA fully utilizes GIS system for maintenance of water pipes and data input of repair record is done through tablet. Its level of inspection and database management is almost the same as that of Japan. It also holds true for many of PWA's 233 branch offices.

Underground installation search equipment is also used, however, equipment for camera survey of inside water pipes is expensive and is difficult to procure because it is not available in Thailand. There may be needs for superior equipment.

As such, new technologies for inspection and database management are already in use and there is a possible market for superior equipment.

2) Pipe materials

In the case study, ductile cast-iron pipe (DIP) and high density polyethylene pipe (DPHE) are suggested as an alternative because they are not in use in Thailand and Japan has comparative advantages. The superiority of Japan is NS type DIP, which was uniquely-invented in Japan to prevent detachment, and thermal fusion bonding technology used for DPHE. If they are procured from Japan in reality, the industrial standard may cause an issue because those materials are made in accordance with the Japanese Industrial Standards (JIS), which is different from the industrial standard in Thailand.

3) Pumps

Many pumps made in Japan are already used in MWA and PWA.