Asset Management Guideline for Irrigation Facilities in Lao People's Democratic Republic

(Summary)

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1. Outline of asset management in irrigation sector

The core component of AM is stock management (management of physical facilities). AM includes fund management and human resource management in addition to stock management. This manual focuses on stock management of irrigation facilities in Southeast Asia.

The AM process for irrigation facilities focusing on stock management is repetition of following sequences.

(1) Daily check and repair of facilities by local engineer in charge.
(2) Regular function diagnosis by regional engineer.
(3) Prediction of deterioration based on diagnosis results, comparison of countermeasures, formulation of function maintenance plan.
(4) Facility monitoring based on facility monitoring plan.
(5) Implementation of countermeasures based on the function maintenance plan and monitoring results.
(6) Accumulation of data on survey and examination results as well as results of countermeasure work.

Irrigation facilities will deteriorate over time after construction is completed, and the functions of the facilities will gradually be lost. In order to maintain the functions of irrigation facilities, appropriate maintenance is required, however, the budget for maintenance is usually limited and the repair / reinforcement of important structures tends to be postponed. Until now, when the lowest limit of the functions of important structures has been reached, renewal of the entire irrigation system has been carried out at a high cost. As investment in irrigation projects progresses, the number of irrigation facilities and the amount of maintenance / renewal cost increases.

In order to maintain the constructed irrigation system under the limited national budget, the irrigation facilities should be regularly evaluated and the budget required for maintenance / repair / reinforcement / renewal should be distributed appropriately. This will result in the extension of service life of the entire facilities. For this purpose, it is necessary to conduct a function diagnosis of facilities for each irrigation system and create a function maintenance plan. The function maintenance plan includes results of function diagnosis, deterioration prediction, priority setting for repair / reinforcement / renewal, method / implementation scenario of countermeasures, calculation of function maintenance cost, and facility monitoring plan.

By introducing AM (stock management), it becomes possible to properly maintain functions of irrigation facilities, extend service life of the facilities, and reduce costs required to maintain functions of facilities. Figure 1.1 shows a comparison between the conventional full renewal work and the function maintenance work through AM.

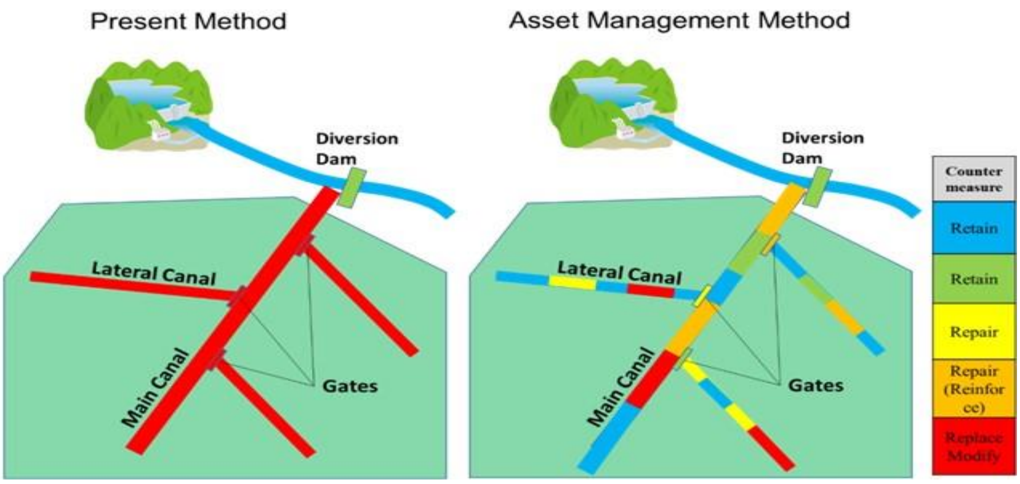


Figure 1.1 Comparison between conventional renewal and asset management

Function diagnosis results are usually divided into five soundness levels according to the degree of deterioration: that is, S-5 for no countermeasure required, S-4 for observation required, S-3 for small-scale repair / reinforcement, S-2 for medium-scale repair / reinforcement, and S-1 for renewal. The facilities are classified into three levels based on the importance of the facility: that is, A for high, B for medium, and C for low importance. As for priority setting to implement countermeasures, the magnitude of risk caused by deterioration of function of facilities should be evaluated based on the degree of deterioration and the importance of facilities. The facility with higher risk is given priority.

Table 1.1 shows a general example of soundness indicators for civil work and machinery.

Table 1.1 Example of soundness indicators for civil works and machinery

Soundness	Facility status*1	Examples of deterioration in reinforced concrete structures	Suggested measures*2
S-5	1) Almost no deterioration 2) No abnormalities	✓ Almost the same as when newly constructed (deterioration is in incubation period)	No action required
S-4	1) Minor deterioration is observed. 2) Minor changes are observed, but there are no functional problems.	✓ Minor cracks or abrasion on concrete ✓ Minor change is observed around joints and structures, but there is no hindrance to normal use. (Deterioration is in progress)	Observation required
S-3	1) Deterioration is noticeable 2) If left unattended, the function will be hindered, and countermeasures are required.	✓ Cracks that reach the rebar have occurred, or concrete peeling has occurred due to corrosion of rebar. ✓ The aggregate has fallen off due to abrasion. ✓ Significant water seepage (running water and fountain) has occurred due to deterioration of joints. (Deterioration process is in transition from the advanced stage to the accelerated stage)	Repair / Reinforcement
S-2	1) Deterioration that affects the structural stability of the facility 2) Function is hindered. Urgent measures are required due to significant degradation.	✓ Cross section of concrete or rebar is partially lost. ✓ Concrete body is clearly deformed due to ground deformation or increase of back earth pressure. (Deterioration process is in transition to the acceleration)	Repair / Reinforcement
S-1	1) Multiple changes that significantly affect structural stability of the facility. Facility function is lost or significantly deteriorated in the near future. Reinforcement is difficult economically and needs to be rebuilt. 2) Reliability of equipment has decreased significantly, and is difficult to repair economically.	✓ Penetration crack is enlarged and effective cross section of rebar is greatly reduced. The deformation evaluated as S-2 has further progressed. ✓ Renewal is more economically advantageous than reinforcement. (in deteriorated stage)	Renewal

*1 Facility status: 1) indicates the status of civil works, and 2) indicates the status of machinery.

*2 The description of this column is provided as a guideline. The necessity of countermeasures corresponding to the soundness rank should be examined according to its importance, risk, deterioration factor, deterioration progress, etc.

Table 1.2 shows an example of criteria for determining repair / renewal by soundness / importance. This table is tentatively based on the following ideas, but since irrigation projects are highly regional, it is necessary to set guidelines for repairs and renewals that suit actual conditions of a country / region.

- In principle, the facility with S-1 should be renewed as soon as possible. If funding or renewal is difficult, temporary important emergency repairs should be carried out to restore functionality.
- The one with S-2 should be renewed within 5 years, and temporary important / normal emergency repairs should be carried out.
- The one with S-3 should be carried out emergency or regular repairs provisionally, with the principle of conducting important repairs within 5 years.

Table 1.2 Image of repair / renewal judgment by soundness / importance

Soundness		S-1			S-2			S-3		
Importance		A	B	C	A	B	C	A	B	C
Renewal	Emergency renewal	◎								
	Normal renewal		◎							
	Renewal within 5 years			◎	◎	◎	◎			
Important repair*	Important emergency repair	◎	◎	◎	◎	◎				
	Important normal repair				○	○	◎			
	Important emergency repair within 5 years						○	◎	◎	◎
Regular repair	Emergency repair	○	○	○	○	○	○	◎		
	Normal repair							○	◎	◎
	Repair within 5 years								○	○

Note) “Important repair” is a large-scale repair that greatly exceeds the “regular repair” level.

Irrigation facility cost should be evaluated by life cycle cost which includes not only construction cost, but also maintenance, repair / reinforcement / renewal cost, and residual value.

AM does not require special additional work when introducing and implementing it. The new work to be introduced by AM is almost limited to the accumulation of data, its analysis, and use of the analyzed results. One of the benefits of AM is evidence-based planning and implementation of irrigation work that can be clearly explained to external stakeholders. The basis for this AM benefit is various information and data collected and accumulated during operation and maintenance (O&M) work. The analysis and use of those data is the key to AM.

Information and data obtained through the implementation of irrigation projects need to be systematically linked and utilized when practicing AM. Furthermore, it is important to collect and accumulate data in order to practice AM more effectively for the future. Expansion of existing ledgers (computerization, addition of input items, etc.) and establishment of a new database is necessary. When establishing, it is desirable to organize information and data by considering ‘what purpose and how much to use’ and ‘how / who will continue to update / input data’.

The irrigation stock management database system accumulates information on irrigation and drainage facility specifications, maintenance and repair history, and function diagnosis results etc. as a system to provide a centralized understanding of facility conditions and to support appropriate function maintenance measures.

Based on the digitized data base, decision makers can decide budget allocation appropriately according to the priority which will be set by soundness and importance evaluation accumulated in the data base. If the domestic resources for repair / reinforcement / rehabilitation / renewal is insufficient, foreign resources should be requested based on the digitized data base through due procedures, in order to avoid function breakdown of irrigation system. The digitized data base will provide an objective material quite useful for explanation to external stakeholders.

2. Function diagnosis

In the function diagnosis, judgment is based on the soundness rank. If there is any deformation, it should be referred to the Table 1.1 and the soundness and importance should be entered to the AM System (Chapter 3) using a smartphone. It is unnecessary to fill in S-4 and S-5 because they do not need to be repaired. The details of the deformation should be entered in the "Memo" column of the AM System as an objective basis for the soundness. If the deformation is large, it is necessary to measure the length, width, and height and add them to the "Memo" column. Since there is no character limit in the "Memo" field, any information can be filled.

In the AM System, coordinates and names of points are automatically set when points are registered. However, since proper names are not set in the automated point names, it becomes difficult to identify the points when tabulated. Therefore, the point names must be changed to the names given to each irrigation facility so that they can be distinguished from others.

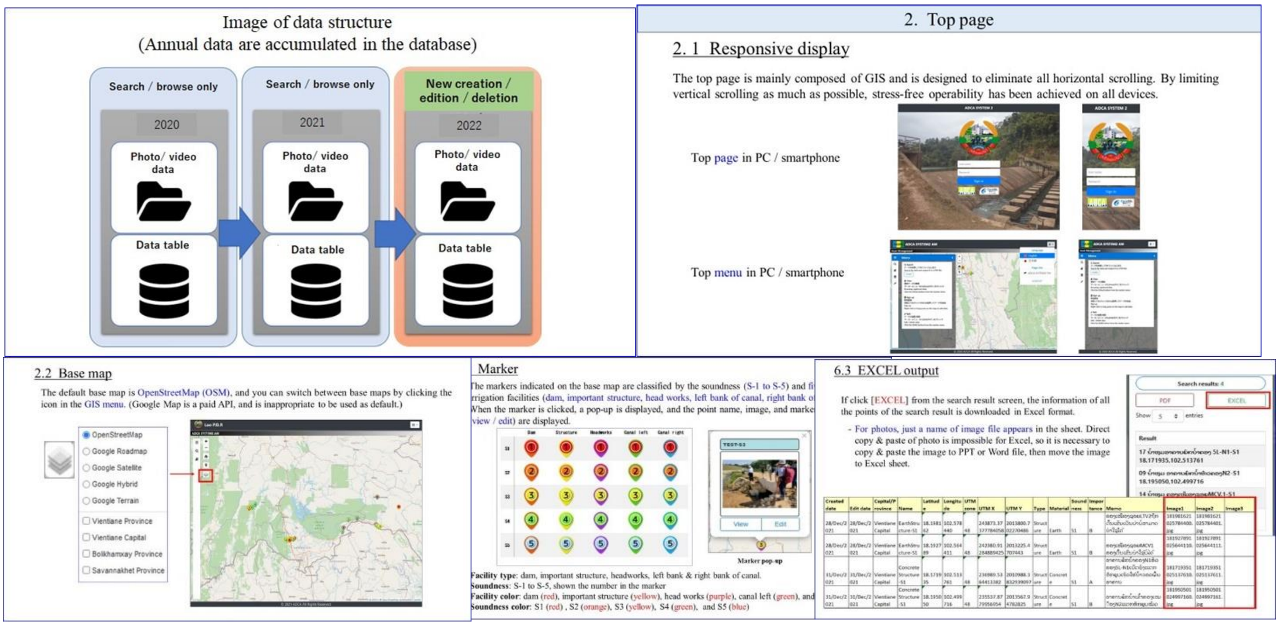
It is necessary to take three photos of each deformed point with a smartphone, and register the photos taken to the AM system. When taking photographs, it is desirable to include 3 types such as a distant view, a near view, and measured state so that the deformed parts can be seen.

3. Visualization and database building of function diagnosis results using AM System

The on-site function diagnosis survey is implemented for each irrigation facility to identify deteriorated or damaged situation, and is consisted of: (i) the confirmation of location to be repaired, (ii) its deterioration status, (iii) the measurement of deformation, (iv) photo taking, etc. Since there are many defective parts in irrigation facilities that have deteriorated, it is desirable to digitize the survey results on-site as much as possible in order to survey without omission and compile them as observed records. The survey results are finally compiled into spreadsheet software such as Excel. A function conservation plan consisting of countermeasure methods (repair, reinforcement or renewal), cost estimation, implementation schedule of countermeasure, etc. is created by sorting and extracting the data and setting priority of countermeasures according to the importance of the facility.

In order to digitize survey results in fields, AM System is used here. By inputting data to AM System with a smartphone, the minimum necessary on-site function diagnosis is possible.

An outline of the AM system is shown below.



4. Function conservation plan

The function conservation plan includes deterioration prediction, priority setting for repair / reinforcement / renewal, countermeasure construction method, countermeasure implementation scenario, function conservation cost calculation, and facility monitoring plan, in addition to the results of function diagnosis. The functional conservation plan can be implemented only when it is financially supported, so the most important is the financial plan based on the results of objective functional diagnosis.

Here, the core of the function conservation plan is regarded as the setting of priorities for repair / reinforcement / renewal and the associated financial plan. Other plans, namely deterioration prediction, countermeasure construction method, countermeasure implementation scenario, function maintenance cost calculation, and facility monitoring plan, are positioned as basic information to complement the financial plan.

As an example, the items and contents of the function conservation plan for the Nam Houm Irrigation System in Vientiane Capital are shown below.

4.1 Summary

The overall outline of the irrigation project subject to the functional conservation plan should be described here, as the following example.

(1) Summary of irrigation project

- Purpose
  The Nam Houm Irrigation System is located in Naxaythong District, Vientiane Capital, and irrigates around 3,497 ha of farmland in 19 villages in Naxaythong District and 2 villages in Xaythani District by providing water from the Nam Houm Dam.

- Construction period
  This project was implemented between 19** and 19** with the support of ****, and was completed in ****, 19**.

- Project cost
  The total project cost is ** LAK.

- Management of irrigation facilities
  The dam and the main canals have been managed by the Nam Houm Irrigation System Office (NISO) of Provincial Agriculture and Forestry Office (PAFO), the Vientiane Capital. Since ****, 20**, the branch canals and below have been managed by three WUAs (WUA1 to WUA3). There are 55 WUGs operating under the three WUAs.

(2) Main irrigation facilities

- Nam Houm Dam
  Completion year: 1978
  Dam type: Earth dam
  Dam height: 22.5 m
  Dam length: 770.0 m
  Width of dam top: 6.0 m
  High water level: ** m
  Low water level: ** m

Total water storage: 60 Mm^3
Effective water storage: 53.8 Mm^3
Dead water storage: 6.0 Mm^3

- Spillway
  Structure: Concrete, Height 2 m, Width 30 m
  Design flood discharge: 122 m^3/sec

- Water intake facility
  Structure: Concrete tower, Concrete conduit, Metal gate
  Water intake: ** Mm^3

- Main canal
  Structure: Concrete
  Length: ** m

- Lateral canals
  Structure: Concrete, Brick, Earth
  Length: Concrete ** m, Brick ** m, Earth ** m

- Check gate
  Structure: Concrete, Steel gate
  Number of gates: ****

- Pumping station (PS)
  Structure: Concrete, Brick building, Horizontal shaft centrifugal pump
  Number of PSs: ****

(3) Positioning of function conservation plan

- This function conservation plan is based on the results of the function diagnosis survey conducted in January 2022, and is a plan to repair and renew the irrigation facilities ranked as S1 to S3, which are particularly deteriorated.
- The repair/renewal period is 5 years.
- The priority of repair and renewal is based on the table 1.2.

(4) Summary of implementation plan

- As the results of the function diagnosis, the points that need to be repaired or renewed are as follows.

S1-A	S1-B	S1-C	S2-A	S2-B	S2-C	S3-A	S3-B	S3-C	Total
2	2			3		2	6		15

- The implementation plan (financial plan) to be completed within 5 years based on the priority of each location after calculating the individual construction cost is as follows.

Sound - impor tance	**Name**	**Quantity**	**Const. period (years)**	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Total**
S1-A	09 ອາຄານຍົກນ້ຳຫົວຄອງເໝືອງ N2-S1	1. Pump 1 2. Pump house 1	2	20,000	15,000				35,000
S1-A	17 ອາຄານຍົກນ້ຳຄອງ 5L-N1-S1	1. Concrete floor 100 m2	1	1,000					1,000
Total				21,000	15,000	0	0	0	36,000
S1-B	15 ຄອງເໝືອງຊອຍ LTV.2 -S1	1. Canal length 2,960 m	4	10,000	30,000	20,000	20,000		80,000
S1-B	14 ຄອງເໝືອງຊອຍMCV.1-S1	1. Canal length 560 m	1	15,000					15,000
Total				25,000	30,000	20,000	20,000	0	95,000
S2-B	03 ປະຕູນ້ຳຫົວງານ-S2	1. Gate 1	2			15,000	15,000		30,000
S2-B	11 ໄລນິງຫົວຄອງເໝືອງN6 -S2	1. Concrete canal 3.5 m	1			1,000			1,000
S2-B	12 ໄລນິງຫົວຄອງເໝືອງN15 -S1	1. Concrete canal 4.0 m	1			2,000			2,000
Total				0	0	18,000	15,000	0	33,000
S3-A	15 ອາຄານຍົກນ້ຳຄອງເໝືອງ N1 -S3	1. Canal 4 m 2. Gate 1	1			7,000			7,000
S3-A	13 ສັນຄອງເໝືອງN15 -S3	1. Canal 1,000 m	2				15,000	15,000	30,000
Total				0	0	7,000	15,000	15,000	37,000
S3-B	04 ຄອງ MC-S3	1. Concrete canal	1					1,000	1,000
S3-B	05 ສັນຄອງເໝືອງ MC-S3	1. Concrete canal	1					2,000	2,000
S3-B	07 ປະຕູນ້ຳຫົວຄອງເໝືອງN1-S3	1. Gate 1	1					10,000	10,000
S3-B	06 ສັນຄອງເໝືອງ MC-S3	1. Concrete canal 500 m	1					15,000	15,000
S3-B	08 ໄລນິງຕາດໂຕນຄອງເໝືອງ MC-S3	1. Concrete canal 6 m	1					500	500
S3-B	07 ໄລນິງຫົວຄອງເໝືອງ N1-S3	1. Concrete canal 3.5 m	1					300	300
Total				0	0	0	0	28,800	28,800
Grand total				46,000	45,000	45,000	50,000	43,800	229,800

4.2 Results of function diagnosis survey

The results of function diagnosis are summarized as follows.

(1) Implementation date

December 28, 2021

(2) Surveyor

Operation and maintenance team of NISO

(3) Method

- Site reconnaissance, visual inspection, simple measurement
- Information input from smartphone to AM system
- Output to EXCEL file of the input result in the office
- Inspection, correction, addition of input information

(4) Judgment of soundness and importance

- Soundness is evaluated in the following five ranks. The data of points ranked as S1 to S3 are input to the AM system.
    - S-5: Sound
    - S-4: Signs of deterioration
    - S-3: Ordinary deterioration
    - S-2: Significant deterioration (management limit level)
    - S-1: Serious deterioration (use limit level)
- Importance is evaluated in the following three ranks.
    - A: High Importance
    - B: Middle
    - C: Low Importance
- Based on the judgment of soundness and importance, the priority of repair/renewal locations is determined.

(5) Results of function diagnosis

- The locations of the deterioration points are shown in the figure below.

- Details of the function diagnosis results for each rank are shown below.

S1-A

Edit date	Capital/ Provinc	Name	UTM	UTM X	UTM Y	Type	Material	Soundness	Importance	Memo	Image1	Image2	Image3
05/Jan/2022	Vientiane Capital	09 ອາຄານພັກນ້ຳ ທີ່ວຄອງເໝືອງ N2-S1	48	235537.8779956954	2013567.94782825	Structure	Concrete	S1	A	ບ້ານຫຼຸມ ອາຄານພັກນ້ຳ ເຂົ້າຄອງເໝືອງN2 ແຕກຫັກຊຸບໂຊມ ເຮັດ ໃຫ້ພັດນ້ຳບໍ່ໄດ້			
05/Jan/2022	Vientiane Capital	17 ອາຄານພັກນ້ຳ ຄອງ SL-N1-S1	48	236989.5364413382	2010988.3832939097	Structure	Concrete	S1	A	ບ້ານຫຼຸມ ອາຄານພັກນ້ຳ ຄອງN1ທີ່ວຄອງSL-N1 ຄອນກຣີດດ້ານໜ້າ ແຕກຫັກຊຸບເຮັດໃຫ້ ນ້ຳລອດພື້ນອາຄານ			

S1-B

Edit date	Capital/Province	Name	UTM zone	UTM X	UTM Y	Type	Material	Soundness	Importance	Memo	Image1	Image2	Image3
05/Jan/2022	Vientiane Capital	15 ຄອງເໝືອງ ຊອຍ LTV.2 -S1	48	243873.37377784058	2013800.702270486	Structure	Earth	S1	B	ບ້ານຫຼຸມ ຄອງເໝືອງຊອຍ LTV2ຖືກຕື້ນເຂີນເປັນປ່າ ບໍ່ສາມາດນ້ຳໃຊ້ໄດ້ມີຄວາມ ຍາວ 2,960 ແມັດ			
05/Jan/2022	Vientiane Capital	14 ຄອງເໝືອງ ຊອຍMCV.1-S1	48	242380.91284889425	2013225.4707443	Structure	Earth	S1	B	ບ້ານຫຼຸມ ຄອງເໝືອງຊອຍ MCV.1ຄອງຕື້ນເຂີນນ້ຳ ໃຊ້ບໍ່ໄດ້ ມີຄວາມຍາວ 560 ແມັດ			

S2-B

Edit date	Capital/Province	Name	UTM zone	UTM X	UTM Y	Type	Material	Soundness	Importance	Memo	Image1	Image2	Image3
05/Jan/2022	Vientiane Capital	03 ປະຕູນ້ຳທົດ ງານ-S2	48	231983.6719735195	2012040.914132953	Structure	Metal	S2	B	ບ້າໜຸ ປະຕູນ້ຳທົດງານທີ່ ແຜ່ນປົກກຽວໜູນແກນ ປະຕູນ້ຳ ແລະ ຕີນເຕົ້າແກນ ປະຕູແຕກທັກເວລາປິດເປີດ ເຮັດແກນຄອນ ແລະຊືມ ນ້ຳມັນເຕົ້າຂາດນ້ຳມັນບໍ່ລື່ນ ຮົ້ວຊືມ			
05/Jan/2022	Vientiane Capital	11 ໄວບົງທົດ ຄອງເໝືອງN6 -S2	48	238199.56209911863	2013315.4483735845	Structure	Concrete	S2	B	ບ້າໜຸ ຄອນກຣີກໄວບົງທົດ ຄອງເໝືອງN6ແຕກ ທັກຫລຸບ, ເປັນໂກນຫຼາຍທົ່ງ ສອງດ້ານ, ມີຄວາມຍາວ 3.5 ແມັດ			
05/Jan/2022	Vientiane Capital	12 ໄວບົງທົດ ຄອງເໝືອງN15 - S1	48	240493.85354420418	2013101.2341725903	Structure	Concrete	S2	B	ບ້າໜຸ ຄອນກຣິດ ໄວບົງທົດ ຄອງເໝືອງN15 ແຕກຫລຸບ ທັງສອງດ້ານ ມີຄວາມຍາວ 4 ແມັດ			

S3-A

Edit date	Capital/Province	Name	UTM zone	UTM X	UTM Y	Type	Material	Soundness	Importance	Memo	Image1	Image2	Image3
05/Jan/2022	Vientiane Capital	15 ອາຄານພັກ ນ້ຳຄອງເໝືອງ N1 -S3	48	235485.48992925143	2012093.1049475854	Structure	Concrete	S3	A	ບ້າໜຸອາຄານພັກຄອງເໝ ືອງ N1 ຄອນກຣິດ ໄວບົງ ດ້ານ ໜ້າ ແຕກຫລຸ ທັງສອງດ້ານ ມີຄວາມຍາວ 4 ແມັດ ແລະ ປະຕູນ້ຳ ບໍ່ສາມາດພັກນ້ຳໄດ້			
05/Jan/2022	Vientiane Capital	13 ລັນຄອງເໝ ືອງN15 -S3	48	242001.96957227497	2012976.91410018	Canal-right	Earth	S3	A B ? (Secondary canal)	ບ້າໜຸ ລັນຄອງເໝືອງN15 ຖືກກັດເຊາະເປັນຂຸມເລິກ ຫຼາຍຈຸດ ທີ່ມີຄວາມຍາວ 1,000 ແມັດ			

S3-B

Edit date	Capital/Province	Name	UTM zone	UTM X	UTM Y	Type	Material	Soundness	Importance	Memo	Image1	Image2	Image3
05/Jan/2022	Vientiane Capital	04 ຄອງ MC-S3	48	232167.00786786218	2012040.1556722992	Canal-right	Concrete	S3	B A ? (Main canal, near dam body)	ບ້າໜຸ ຄອນກຣິດ ໄວບົງ ທັງຜ່ເຂົ້ານ້ຳທົດຄອງ MC ແຕກທັກເປັນໂກນ			
05/Jan/2022	Vientiane Capital	05 ລັນຄອງເໝ ືອງ MC-S3	48	232627.12571422267	2012374.9120839182	Canal-right	Earth	S3	B A ? (Main canal, near dam body)	ລັດແທກຄອງເໝືອງ ແມ່ນ້ຳໜຸມທີ່ຖືກກັດເຊາະ ເພື່ອນເປເສslope deformation			
05/Jan/2022	Vientiane Capital	07 ປະຕູນ້ຳທົດ ຄອງເໝືອງN1-S3	48	232962.4337340297	2012364.0939498085	Structure	Metal	S3	B A ? (Main canal, diversion gate)	ບ້າໜຸ ປະຕູນ້ຳທົດຄອງ N1 ກຽວປິ່ນປະຕູນ້ຳ ແຕກ ເຮັດໃຫ້ປິດ-ເປີດນ້ຳຍາກ			
05/Jan/2022	Vientiane Capital	06 ລັນຄອງເໝ ືອງ MC-S3	48	232752.80003180198	2012376.614328074	Canal-right	Earth	S3	B A ? (Main canal, near dam)	ບ້າໜຸ ລັດແທກຄວາມ ຍາວເຂື່ອນທາງລັນຄອງເໝ ືອງແມ່ MC ເບື້ອງຂ້ວ ເປັນຂຸມເລິກ ມີຄວາມຍາວ 500 ແມັດ			
05/Jan/2022	Vientiane Capital	08 ໄວບົງດາດ ໂຕນຄອງເໝ ືອງMC-S3	48	235048.22181822552	2013753.372495266	Structure	Concrete	S3	B	ບ້າໜຸຝາກັ້ນເຈື່ອນທ້າຍ ດາດໂຕນຄອງເໝືອງMc ແຕກທັກ ຫລຸບ ສອງດ້ານ ມີຄວາມຍາວ 6 ແມັດ			
05/Jan/2022	Vientiane Capital	07 ໄວບົງທົດ ຄອງເໝືອງ N1-S3	48	232948.67429090664	2012356.5310266607	Canal-right	Earth	S3	B A ? (Main canal, near diversion)	ບ້າໜຸ ຄອນກຣິດ ໄວບົງ ທົດຄອງ N1 ແຕກຫລຸບ ເປັນໂກນ ສອງດ້ານ ຍາວ 3.5 ແມັດ			

4.3 Cost calculation

The calculation method of the construction cost is as follows.

- The repair / renewal quantity for each deterioration point is estimated by simple measurement as much as possible.
- As a general, when repairing or renewing, the original shape should be restored. However, regarding the repair / renewal construction method, the most advantageous technology should be adopted based on the calculation results of the life cycle cost **(Annex A1)**.

- In order to facilitate the calculation of repair / renewal quantity and cost, standardization will be made as much as possible.
- The work unit price (labor cost, material cost, machine use cost) shall be that of *** month, *** year.
- For repair / renewal work requiring a large amount of money, several construction methods should be compared. When comparing those methods, not only cost, but also easiness of construction, possibility of material procurement, and construction period should be considered. When comparing costs, life cycle cost should be used instead of investment (capital) cost. Also, in order not to delay the start of repair / renewal work for important structures, a deterioration curve should be created to estimate the start deadline **(Annex A2)**.

Below are examples of construction cost calculations for each degree of soundness and importance.

S1-A

Capital/Province	Name	Memo	Type Repair/ Renewal	Quantity	Cost	Construction period (years)	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Vientiane Capital	09 ອາຄານຍົກນ້ຳ ຫົວຄອງເໜືອງ N2-S1	ນ້ຳຫຼຸ ອາຄານຍົກນ້ຳເຂົ້າ ຄອງເໜືອງN2ແຕກຫັກ ຍຸບໝົດ ເຮັດໃຫ້ຍົກນ້ຳບໍ່ໄດ້	Renewal	1. Pump 1 2. Pump house 1	1. 15,000 $ 2. 20,000 $	2	20,000	15,000				35,000
Vientiane Capital	17 ອາຄານຍົກນ້ຳ ຄອງ 5L-N1-S1	ນ້ຳຫຼຸ ອາຄານຍົກນ້ຳຄອງ N1ຫົວຄອງ5L-N1 ຄອນກຣີດດ້ານໜ້າ ແຕກ ຫັກຍຸບເຮັດໃຫ້ນ້ຳລອດພື້ນ	Repair	1. Concrete floor 100 m^2	1. 1,000 $	1	1,000					1,000
Total	2						21,000	15,000				36,000

S1-B

Capital/ Province	Name	Memo	Type Repair/ Renewal	Quantity	Cost	Construction period (years)	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Vientiane Capital	15 ຄອງເໝືອງຊອຍ LTV.2 -S1	ນ້ຳຫຼຸ ຄອງເໝືອງຊອຍ LTV2ຖືກຕື້ນເຂີນເປັນປ່າບໍ່ ສາມາດນຳໃຊ້ໄດ້ມີຄວາມຍາວ 2,960 ແມັດ	Renewal from earth to concrete canal	1. Canal length 2,960 m	80,000 $	4	10,000	30,000	20,000	20,000		80,000
Vientiane Capital	14 ຄອງເໝືອງຊອຍ MCV.1-S1	ນ້ຳຫຼຸ ຄອງເໝືອງຊອຍ MCV.1ຄອງຕື້ນເຂີນນຳໃຊ້ບໍ່ ໄດ້ ມີຄວາມຍາວ 560 ແມັດ	Renewal from earth to concrete canal	1. Canal length 560 m	15,000 $	1	15,000					15,000
Total	2						25,000	30,000	20,000	20,000		95,000

S2-B

Capital/ Province	Name	Memo	Type Repair/ Renewal	Quantity	Cost	Construction period (years)	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Vientiane Capital	03 ປະຕູນ້ຳຫົວງານ-S2	ນ້ຳຫຼຸ ປະຕູນ້ຳຫົວງານທີ່ແຜ່ນ ປີກກຽວໝູນແກນປະຕູນ້ຳ ແລະ ຕີນເຕົ້າແກນປະຕູແຕກຫັກ ເວລາປິດເປີດເຮັດແກນຄອນ ແລະຊີນນ້ຳມັນເຕົ້າຂາດນ້ຳມັນລ່ ລື້ນຮື່ອຊືມ	Renewal	1. Gate 1	30,000 $	2	15,000	15,000				30,000
Vientiane Capital	11 ໄລນິງຫົວ ຄອງເໜືອງN6 - S2	ນ້ຳຫຼຸ ຄອນກຣີດໄລນິງຫົວ ຄອງເໜືອງN6ແຕກຫັກຫຼຸບ, ເປັນໂກນຫຼາຍທັງສອງດ້ານ, ມີ ຄວາມຍາວ 3.5 ແມັດ	Repair	1. Concrete canal 3.5 m	1,000 $	1	1,000					1,000
Vientiane Capital	12 ໄລນິງຫົວ ຄອງເໜືອງN15 -S1	ນ້ຳຫຼຸ ຄອນກຣີດ ໄລນິງຫົວ ຄອງເໜືອງN15 ແຕກຫຼຸບ ທັງ ສອງດ້ານ ມີຄວາມຍາວ 4 ແມັດ	Repair	1. Concrete canal 4.0 m	2,000 $	1	2,000					2,000
Total	3						18,000	15,000				33,000

S3-A

Capital/ Province	Name	Memo	Type Repair/ Renewal	Quantity	Cost	Construction period (years)	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Vientiane Capital	15 ອາຄານຍົກ ນ້ຳຄອງເໜືອງ N1 -S3	ນ້ຳຫຸມອາຄານຍົກຄອງເໜືອງ N1 ຄອນກຣີດ ໄວນິງດ້ານ ໜ້າ ແຕກຫປູ ທັງສອງດ້ານມີ ຄວາມຍາວ 4 ແມັດ ແລະ ປະຕູ ນ້ຳ ບໍ່ສາມາດຍົກນ້ຳໄດ້	Repair	1. Canal 4 m 2. Gate 1	1. 3,000 $ 2. 4,000 $	1	7,000					7,000
Vientiane Capital	13 ສັນຄອງເໜ ືອງN15 -S3	ນ້ຳຫຸມ ສັນຄອງເໜືອງN15 ຖືກກັດເຊາະເປັນຂຸມເລິກ ຫຼາຍ ຈຸດ ທີ່ມີຄວາມຍາວ 1,000 ແມັດ	Renewal from earth to concrete canal	1. Canal 1,000 m	1. 30,000 $	2	15,000	15,000				30,000
Total	2						22,000	15,000				37,000

S3-B

Capital/ Province	Name	Memo	Type Repair/ Renewal	Quantity	Cost	Construction period (years)	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Vientiane Capital	04 ຄອງ MC-S3	ນ້ຳຫຸມ ຄອນກຣີດ ໄວນິງທ້າຍທໍ່ເອົານ້ຳຫົວຄອງ MC ແຕກຫັກເປັນໂກນ	Repair	1. Concrete canal	1. 1,000 $	1	1,000					1,000
Vientiane Capital	05 ສັນຄອງເໜ ືອງ MC-S3	ວັດແທກຄອງເໜືອງແມ່ນ້ຳ ຫຸມທີ່ຖືກກັດເຊາະເຈື່ອນເປເພ slope deformation	Repair	1. Concrete canal	1. 2,000 $	1	2,000					2,000
Vientiane Capital	07 ປະຕູນ້ຳຫົວ ຄອງເໜືອງ N1-S3	ນ້ຳຫຸມ ປະຕູນ້ຳຫົວຄອງ N1 ກຽວປີ່ນປະຕູນ້ຳ ແຕກເຮັດໃຫ້ ປິດ-ເປີດນ້ຳຍາກ	Renewal	1. Gate 1	1. 10,000 $	1	10,000					10,000
Vientiane Capital	06 ສັນຄອງເໜ ືອງ MC-S3	ນ້ຳຫຸມ ວັດແທກຄວາມຍາວ ເສັ້ນທາງສັນຄອງເໜືອງແມ່ MC ເບື້ອງຂ້ວເປັນຂຸມເລິກ ມີ ຄວາມຍາວ 500 ແມັດ	Repair from earth to concrete canal	1. Concrete canal 500 m	1. 15,000 $	1	15,000					15,000
Vientiane Capital	08 ໄວນິງຕາດ ໂຕນຄອງເໜ ືອງMC-S3	ນ້ຳຫຸມຝາກັ້ນເຈື່ອນທ້ານຕາດ ໂຕນຄອງເໜືອງMc ແຕກຫັກ ຫລຸຍ ສອງດ້ານ ມີຄວາມຍາວ 6 ແມັດ	Repair	1. Concrete canal 6 m	1. 500 $	1	500					500
Vientiane Capital	07 ໄວນິງຫົວ ຄອງເໜືອງ N1-S3	ນ້ຳຫຸມ ຄອນກຣີດ ໄວນິງຫົວ ຄອງ N1 ແຕກຫລູບ ເປັນໂກນ ສອງດ້ານ ຍາວ 3.5 ແມັດ	Repair	1. Concrete canal 3.5 m	1. 300 $	1	300					300
Total	6						28,800					28,800

The total construction cost is shown in the table below.

Soundness/ Importance	Number of points	Cost (USD)					
		Year 1	Year 2	Year 3	Year 4	Year 5	Total
S1-A	2	21,000	15,000				36,000
S1-B	2	25,000	30,000	20,000	20,000		95,000
S2-B	3	18,000	15,000				33,000
S3-A	2	22,000	15,000				37,000
S3-B	6	28,800					28,800
	15	114,800	75,000	20,000	20,000	0	229,800

4.4 Budget allocation plan

The concept of the budget allocation plan is as follows.

- It is assumed that the total budget required for repair and renewal will be evenly distributed over five years.
- In order of priority, S1-A has the highest priority and S3-C has the lowest priority.
- If the budget for the first year is not secured, it will be passed on to the next year in descending order of priority.
- The five-year plan will be reviewed every fiscal year. At this time, the soundness level is changed to S4 or S5 for the point where repair/renewal is completed, and it is excluded from the AM system in the next year.

When the fiscal year changes, the data of the previous fiscal year is accumulated as a database, so the data will not be erased.

Details of the five-year budget allocation plan are shown in the table below.

Sound / import	Capital / Province	Name	Memo	Type Repair/ Renewal	Quantity	Cost	Construction period (years)	Year 1	Year 2	Year 3	Year 4	Year 5	Total
S1-A	Vientiane Capital	09 ອາຄານຍົກນ້ຳຫົວຄອງເໝືອງN2-S1	ບ້ຳຫຸມ ອາຄານຍົກນ້ຳເຂົ້າຄອງເໝືອງN2ແຕກຫັກຍຸບໝົດ ເຮັດໃຫ້ຍົດນ້ຳບໍ່ໄດ້	Renewal	1. Pump 1 2. Pump house 1	1. 15,000 $ 2. 20,000 $	2	20,000	15,000				35,000
S1-A	Vientiane Capital	17 ອາຄານຍົກນ້ຳຄອງ 5L-N1-S1	ບ້ຳຫຸມ ອາຄານຍົກນ້ຳຄອງN1 ຫົວຄອງ5L-N1 ຄອນກຣີດ ດ້ານໜ້າ ແຕກຫັກຍຸບເຮັດໃຫ້ນ້ຳລອດພື້ນອາຄານ	Repair	1. Concrete floor 100 m2	1. 1,000 $	1	1,000					1,000
Total								21,000	15,000	0	0	0	36,000
S1-B	Vientiane Capital	15 ຄອງເໝືອງ ຊອຍ LTV.2 -S1	ບ້ຳຫຸມ ຄອງເໝືອງຊອຍLTV2 ຖືກຕື້ນເຂີນເປັນປ່າບໍ່ສາມາດນຳໃຊ້ໄດ້ມີຄວາມຍາວ 2,960 ແມັດ	Renewal from earth to concrete canal	1. Canal length 2,960 m	80,000 $	4	10,000	30,000	20,000	20,000		80,000
S1-B	Vientiane Capital	14 ຄອງເໝືອງ ຊອຍMCV.1-S1	ບ້ຳຫຸມ ຄອງເໝືອງຊອຍ MCV.1ຄອງຕື້ນເຂີນບໍ່ໃຊ້ບໍ່ໄດ້ ມີຄວາມຍາວ 560 ແມັດ	Renewal from earth to concrete canal	1. Canal length 560 m	15,000 $	1	15,000					15,000
Total								25,000	30,000	20,000	20,000	0	95,000
S2-B	Vientiane Capital	03 ປະຕູນ້ຳຫົວງານ-S2	ບ້ຳຫຸມ ປະຕູນ້ຳຫົວງານທີ່ແຜ່ນປິກກຽວໜູນແກນປະຕູນ້ຳ ແລະ ຕີນເຕົ້າແກນປະຕູແຕກຫັກ ເວລາປິດເປີດເຮັດແກນຄອນ ແລະຊືບນ້ຳມັນເຕົ້າຂາດນ້ຳມັນ ລ່ລື່ນຮ໋ອຊີມ	Renewal	1. Gate 1	30,000 $	2			15,000	15,000		30,000
S2-B	Vientiane Capital	11 ໄວບົງຫົວ ຄອງເໝືອງN6 - S2	ບ້ຳຫຸມ ຄອນກຣີກໄວບົງຫົວ ຄອງເໝືອງN6ແຕກຫັກຫຼຸບ, ເປັນໂກນຫຼາຍທັງສອງດ້ານ, ມີ ຄວາມຍາວ 3.5 ແມັດ	Repair	1. Concrete canal 3.5 m	1,000 $	1			1,000			1,000
S2-B	Vientiane Capital	12 ໄວບົງຫົວ ຄອງເໝືອງN15 -S1	ບ້ຳຫຸມ ຄອນກຣີດ ໄວບົງຫົວ ຄອງເໝືອງN15 ແຕກຫຼຸບ ທັງສອງດ້ານ ມີຄວາມຍາວ 4 ແມັດ	Repair	1. Concrete canal 4.0 m	2,000 $	1			2,000			2,000
Total								0	0	18,000	15,000	0	33,000
S3-A	Vientiane Capital	15 ອາຄານຍົກນ້ຳຄອງເໝືອງ N1 -S3	ບ້ຳຫຸມອາຄານຍົກຄອງເໝືອງ N1 ຄອນກຣີດ ໄວບົງດ້ານໜ້າ ແຕກຫຼຸ ທັງສອງດ້ານມີ ຄວາມຍາວ 4 ແມັດ ແລະ ປະຕູນ້ຳ ບໍ່ສາມາດຍົກນ້ຳໄດ້	Repair	1. Canal 4 m 2. Gate 1	1. 3,000 $ 2. 4,000 $	1			7,000			7,000
S3-A	Vientiane Capital	13 ສັນຄອງເໝືອງN15 -S3	ບ້ຳຫຸມ ສັນຄອງເໝືອງN15ຖືກກັດເຊາະເປັນຂຸມເລິກ ຫຼ້າຍຈຸດ ທີ່ມີຄວາມຍາວ 1,000 ແມັດ	Renewal from earth to concrete canal	1. Canal 1,000 m	1. 30,000 $	2				15,000	15,000	30,000
Total								0	0	7,000	15,000	15,000	37,000
S3-B	Vientiane Capital	04 ຄອງ MC-S3	ບ້ຳຫຸມ ຄອນກຣີດ ໄວບົງທ້າຍທໍ່ເອົານ້ຳຫົວຄອງ MC ແຕກຫັກເປັນໂກນ	Repair	1. Concrete canal	1. 1,000 $	1					1,000	1,000
S3-B	Vientiane Capital	05 ສັນຄອງເໝືອງ MC-S3	ວັດແທກຄອງເໝືອງແມ່ນ້ຳຫຸມ ທີ່ຖືກກັດເຊາະເຈື່ອນເປເພslope deformation	Repair	1. Concrete canal	1. 2,000 $	1					2,000	2,000
S3-B	Vientiane Capital	07 ປະຕູນ້ຳຫົວ ຄອງເໝືອງN1-S3	ບ້ຳຫຸມ ປະຕູນ້ຳຫົວຄອງ N1 ກຽວປີ່ນປະຕູນ້ຳ ແຕກເຮັດໃຫ້ ປິດ-ເປີດນ້ຳຍາກ	Renewal	1. Gate 1	1. 10,000 $	1					10,000	10,000
S3-B	Vientiane Capital	06 ສັນຄອງເໝືອງ MC-S3	ບ້ຳຫຸມ ວັດແທກຄວາມຍາວ ເສັ້ນທາງສັນຄອງເໝືອງແມ່ MC ເບື້ອງຂ້ອເປັນຂຸມເລິກ ມີຄວາມ ຍາວ 500 ແມັດ	Repair from earth to concrete canal	1. Concrete canal 500 m	1. 15,000 $	1					15,000	15,000
S3-B	Vientiane Capital	08 ໄວບົງດາດ ໂຕນຄອງເໝືອງ MC-S3	ບ້ຳຫຸມຜາກັນເຈື່ອນທ້ານດາດ ໂຕນຄອງເໝືອງMc ແຕກຫັກ ຫຼຸຍ ສອງດ້ານ ມີຄວາມຍາວ 6 ແມັດ	Repair	1. Concrete canal 6 m	1. 500 $	1					500	500
S3-B	Vientiane Capital	07 ໄວບົງຫົວ ຄອງເໝືອງ N1-S3	ບ້ຳຫຸມ ຄອນກຣີດ ໄວບົງຫົວຄອງ N1 ແຕກຫຼຸບ ເປັນໂກນ ສອງ ດ້ານ ຍາວ 3.5 ແມັດ	Repair	1. Concrete canal 3.5 m	1. 300 $	1					300	300
Total								0	0	0	0	28,800	28,800
Grand total								46,000	45,000	45,000	50,000	43,800	229,800

Annex

Annex 1 Life cycle cost

Function maintenance cost is calculated as a life cycle cost (LCC). For irrigation facilities, a series of processes from survey, planning, design, construction, operation, maintenance, renewal and disposal is called the life cycle, and all cost required during this period is called LCC. In general, LCC is expressed by the following equation.

LCC = initial construction cost + maintenance cost + renewal / disposal cost - residual value

Until now, irrigation facilities were often planned mainly by comparing only the initial construction cost. However, the introduction of LCC evaluation enables the most advantageous and efficient investment in the life cycle.

LCC calculation begins by assuming various cases as the life cycle of irrigation facilities. An important item in calculating LCC is the service life. For the service life, there are physical life, economic life, functional life, and social planning life. In calculating LCC, economic life is often set as the service life, but in practice, it is determined with reference to past cases and deterioration prediction data.

As an example, the service life for each canal type is shown in Table A1.1.

Table A1.1 Service life and renovation scenario for canal type

Canal type	Standard service life[*1]	Renovation scenario		
		Description	Frequency	Cost
Concrete canal	40 years	Partial renovation	Once in 20 years	10% of the construction cost[*2]
Masonry canal	30 years	Complete renovation	Once in 30 years	100% of construction cost[*2]
Brick canal	20 years	Complete renovation	Once in 20 years	100% of construction cost[*2]
Earth canal	10 to 20 years	Complete renovation	Once in 15 years	100% of construction cost[*2]

*1 MAFF. 2017. *2 Construction cost excludes land acquisition cost. Source) JIID. 2018.

For LCC, it is necessary to calculate construction cost, maintenance cost, countermeasure cost, and disposal cost according to the current unit price, allocate the cost every year, discount them at a social discount rate (SDR), and convert them to present values.

SDR is a discount rate used in computing the value of funds spent on social projects. Determining this rate is not always easy and can be the subject of discrepancies in certain projects, plans and policies. The discount rate is considered as a critical element in cost-benefit analysis when costs and benefits differ in their distribution over a long time. The formula for calculating LCC is shown in below.

$$LCC = CI + \sum_t (CM + CR) F_{pw}(t) \quad , \qquad F_{pw}(t) = (1+i)^{-t}$$

LCC : Life cycle cost

CI : Initial cost (labor cost + material cost + machine operation cost + land acquisition cost)

CM : Operation and maintenance cost

CR : Renovation cost

$F_{pw}(t)$: Present value coefficient (t annual discount coefficient)

i : Social discount rate t : Year

If (elapsed year > useful life) then {(1 - elapsed year / useful life) = 0} is used

Excel has a following function to calculate net present value:

NPV(discount rate, value1:valueN)

The proper discount rate should represent the opportunity cost of what else the project could accomplish with those same funds. For example, if the money could be used to invest in the private sector that would yield 5% of benefit and that is the next best alternative for using that money instead of irrigation project, then 5% would be the social discount rate.

The US government uses a variety of discount rates but something around 7% is what the US Office of Management and Budget (OMB) recommends for a pretax rate of return on private investments. In the United Kingdom, HM Treasury fixes the social discount rate for the public sector at 3.5%.

Example of SDR in Asia is shown in Table A1.2.

Table A1.2 SDR in Japan and Southeast Asia

Social Discount Rate (SDR)		Application
Japan	4%	Current value used in irrigation project
	0%	Japanese government bond yield (2016 - 2017)
Southeast Asia	9%	Value used by Asian Development Bank
	2.6%	Yield of government bonds in Thailand

Source) JIID. 2018

As an example of LCC calculation, the case of canal types is compared among non-lined canals, brick canals, stone masonry canals, concrete canals, and precast concrete canals. At this time, the water discharge capacity not the cross section is common to all types, the evaluation period is 40 years, and the SDR is 4%. The service life is 10 years for non-lined canals, 20 years for brick canals, 25 years for stone masonry canals, 35 years for concrete canals, and 40 years for precast concrete canals. The annual maintenance cost is assumed to be 30% of the construction cost for non-lined canals, 10% for brick canals, 10% for stone masonry canals, 1% for concrete canals, and 0.5% for precast concrete canals.

The calculation results are shown in Figure A1.2 and are as follows in order of LCC size.

NPV (USD) = 298,519 (stone masonry) > 238,381 (no lining) > 203,402 (brick) > 166,613 (concrete cast in place) > 109,896 (precast concrete)

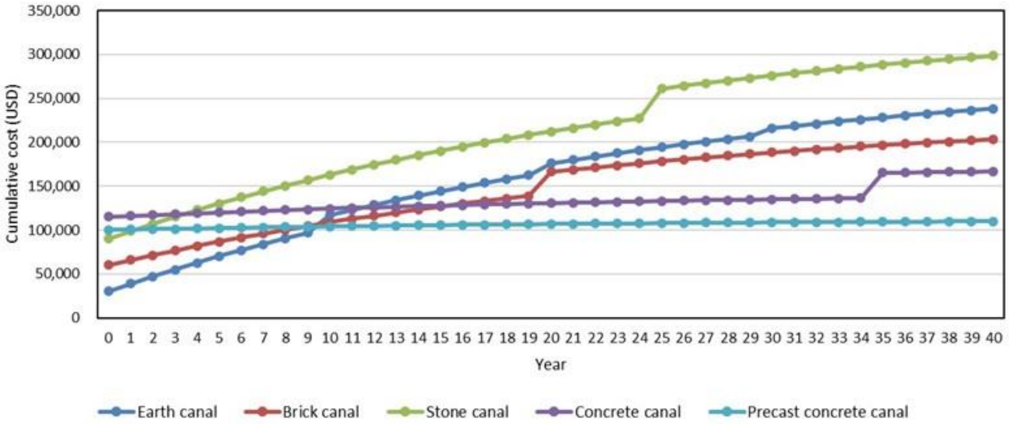


Figure A1.2 LCC comparison by channel type

In FigureA1.2, the initial cost of non-lined canal is the cheapest, but the maintenance cost is high, so the LCC is high. The initial cost of stone masonry canals and brick canals are cheaper than concrete canals, but their maintenance costs are high and their service life is short, so their LCC is higher than concrete canals. On the other hand, precast concrete canals are the most expensive to construct, but have a long service life and low maintenance costs, making LCC the cheapest. That is, in this example, precast concrete canals should be selected.

Annex 2 Deterioration prediction

Deterioration prediction is carried out for the purpose of comparing and examining the time and method of countermeasures required for each facility / equipment.

The deterioration of concrete facility proceeds under the influence of internal factor, external factor, and other factors. The dominant factor among these should be determined, thereafter a deterioration prediction based on these factors should be made. For machinery and equipment (gate, etc.), prediction of remaining life should be determined based on diagnosed characteristics of deterioration.

A standard deterioration curve is drawn by using the results of function diagnosis survey conducted in Japan so far (Figure A2.1). However, the data used as the basis of the curve has a large variation.

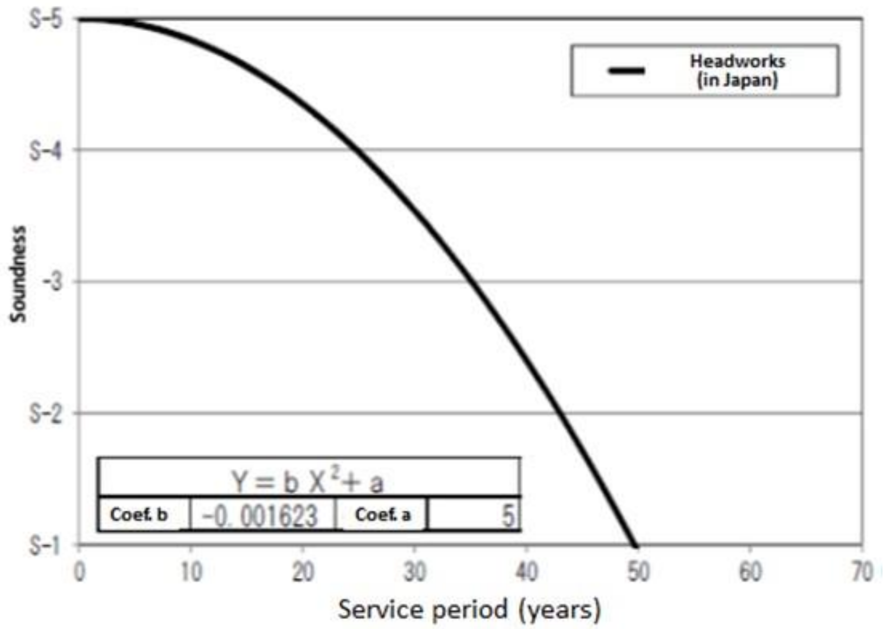


Figure A2.1 Standard deterioration curve drawn based on the data of headworks survey in state-run irrigation system in Japan

Deterioration curve can be easily drawn by recording changes in soundness over time.

For example, if soundness of a concrete structure was recorded after the first year, 10 years, 20 years, and 30 years as shown in Table A2.1, a regression equation (deterioration curve) of a quadratic curve (Soundness = $5\text{-}ax^2 + bx$) or a straight line (Soundness = 5 - ax) is obtained when year is expressed as 'x' (Figure A2.2). In this example, the year when soundness becomes S-1 is 38.7 years after construction for the quadratic curve and 56 years for the straight line.

Table A2.1 Example of changes in soundness over time

Year	Soundness
0	5
10	4.5
20	4
30	2.5

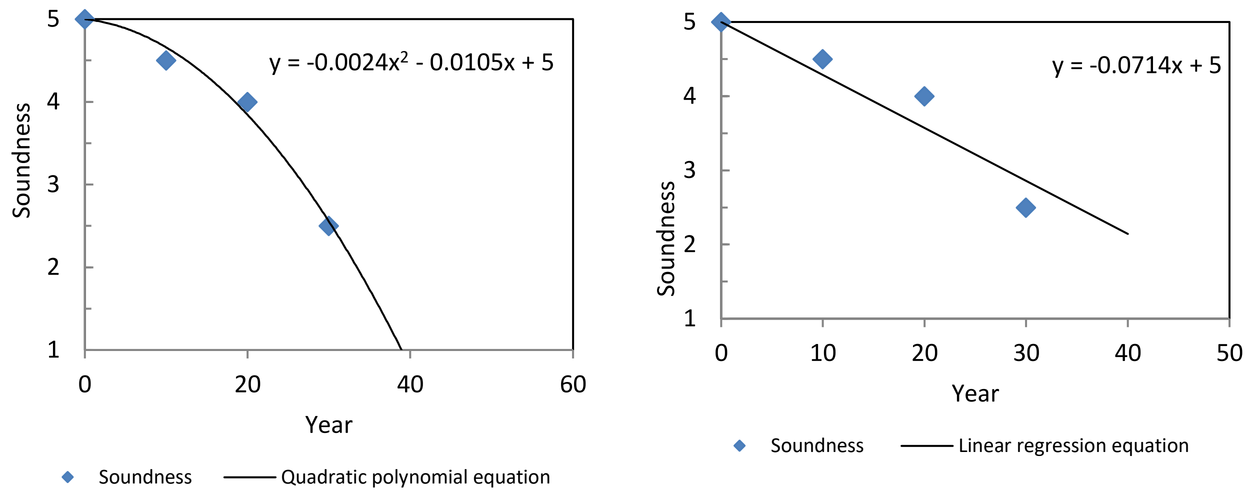


Figure A2.2 Example of calculated deterioration curve

There is a method of remaining life prediction by using the results of detailed diagnosis survey for deterioration prediction of facility and equipment (metal gate, etc.) that gradually degrades over time. In this method, the progress of abrasion / corrosion amount of a surveyed site and the degree of change in the insulation resistance value is compared with an allowable value or a criterion of the facility / equipment. For example, if abrasion has progressed for 2 mm in 20 years, the remaining life is predicted to be 10 years, when the allowable value is set as 3 mm.

Figure A2.3 shows the concept of remaining life of facility / equipment.

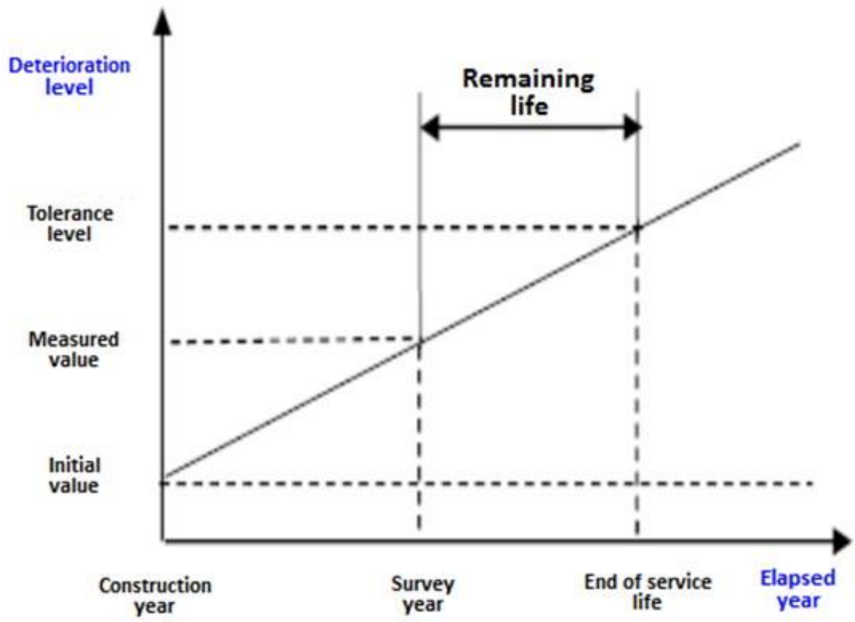


Figure A2.3 Concept of remaining life of facility / equipment

Note) Tolerance level: Amount of deterioration that does not affect the functionality of facility