SUSTAINABILITY APPROACHES ADOPTED FOR STORMWATER AND DEPOSIT PONDS CONSTRUCTION OF ANKENG MRT SYSTEM IN NEW TAIPEI CITY

Dr. Tai-Yi Liu *, Cheng-An Lee, Mao-Yi Chou, Pei-Hsuan Chang, Jui-Jiun Lin & Wen-Chung Lan
*Professional Engineer, New Asia Construction and Development Corp., Taipei City, Taiwan, R.O.C.
Director, Department of Rapid Transit Systems, New Taipei City, Taiwan, R.O.C.
Project Manager, Department of Rapid Transit Systems, New Taipei City, Taiwan, R.O.C.
Leader Engineer, Department of Rapid Transit Systems, New Taipei City, Taiwan, R.O.C.
Leader Engineer, Department of Rapid Transit Systems, New Taipei City, Taiwan, R.O.C.
Site Engineer, New Asia Construction and Development Corp., Taipei City, Taiwan, R.O.C

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ABSTRACT
The Ankeng Light Rail MRT System (ALRMS) is one of the most critical transportation project, which is located in New Taipei City, Taiwan. The ALRMS is under construction and is expected to be finished and serve to transportation in 2022. One of the most significant environmental achievements is the adoption of the sustainable method for the construction of the basin, which is for temporary storage of the silts/debris. Several methods were evaluated in this project. The engineers determine to use the gabion structure to replace the traditional RC structure for the Storm water and Deposit Ponds (SDPs) construction. The materials of the gabion structure are taken from nature. It could significantly reduce the use of cement, rebar, formworks, and other materials which are produced by the human. Not only the carbon emission can be massively reduced, but also the construction duration is drastically shortened. Furthermore, the ecological conservation issue is also taken care in the construction of the SDPs. This experience could be served as a valuable reference for the sustainability development of other similar infrastructure projects.

INTRODUCTION
Due to global warming, recently in the world, the “sustainability” issues for the lifecycle of infrastructures are more and more concerned and discussed during the development of the projects. Specifically, “green” infrastructures are being emphasized through designs and constructions that support long-term sustainability. Not only in Taiwan but also global, the “green building” assessment systems had been well established and applied for the development of building projects. In Taiwan, it is a regulation to apply the EEWH assessment system for public building projects [1-8].

The Ankeng Light Rail MRT System (ALRMS), which is a 7.5 km length project, includes nine stations. It contains four grounded stations, and five elevated stations, respectively [9]. The client of the ALRMS is the Department of Rapid Transit Systems (DRTS), New Taipei City. A depot zone is the heart of the entire ALRMS project. The major facilities of the depot, including some functional factories, are listed as follows:

- Rails and Turnout system.
- Administration building.
- Train parking and storage factory.
- Train maintenance factory.
- Access bridge for train entering and departure.
- Approaching and connection roads.
- Dewatering box culvert.
- Permanent Stormwater and Deposit Ponds (SDPs).
- Utilities.

Leading study in this paper

Figure 1 shows the layout for the depot zone of the ALRMS project.
In this paper, the red color indicated “Permanent Stormwater and Deposit Ponds (SDP)” items listed above is the leading study item. The primary functions of the SDPs are to temporarily store the soil/debris to reduce the

quantity of the soil/debris deposited to the dewatering system. It is one of the most critical facilities in the drainage system. The structure of the SDPs could be designed with more consideration of sustainability. The evaluation and determination for those sustainability issues are discussed in this paper.

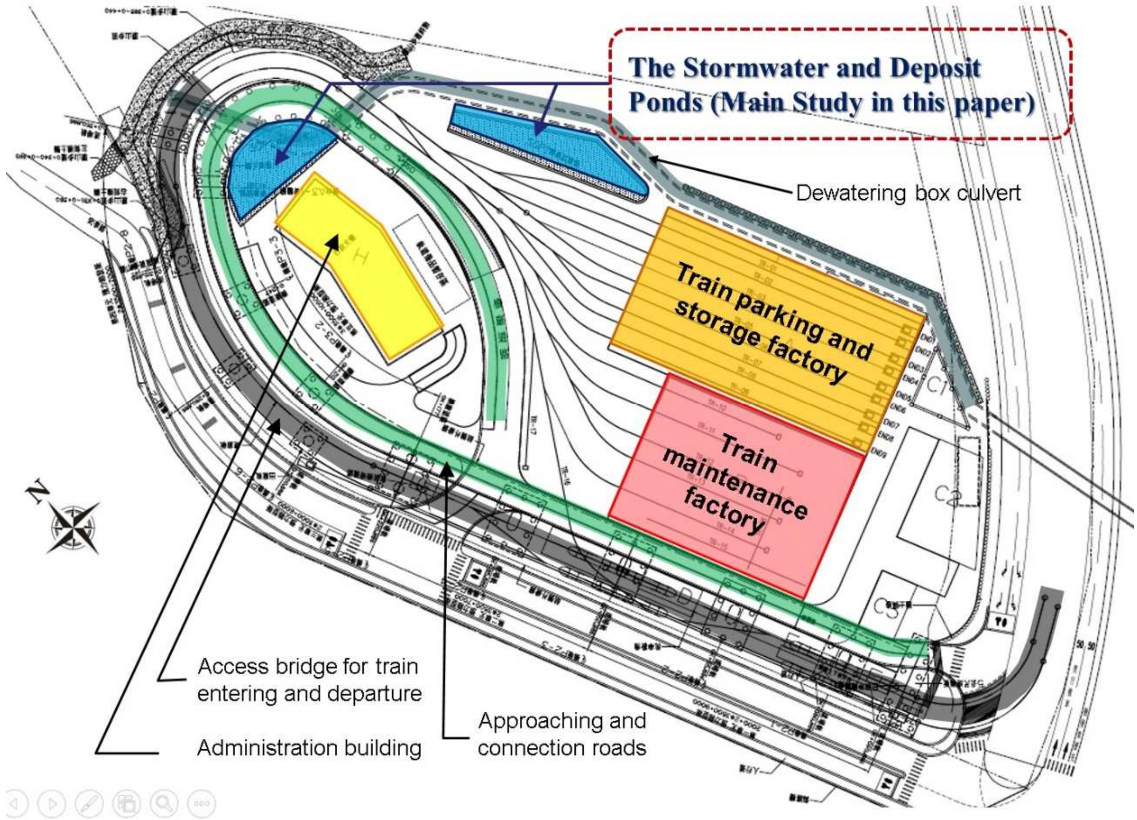

Figure 1 The layout for the depot zone of the ALRMS project

The water and soil conservation work is an essential practice for the development of infrastructures [10]. Thus, the measures of the efficiency of the water and soil conservation practice are based on the three parts: physical measures, biological measures, and agronomic measures, as shown in figure 2.

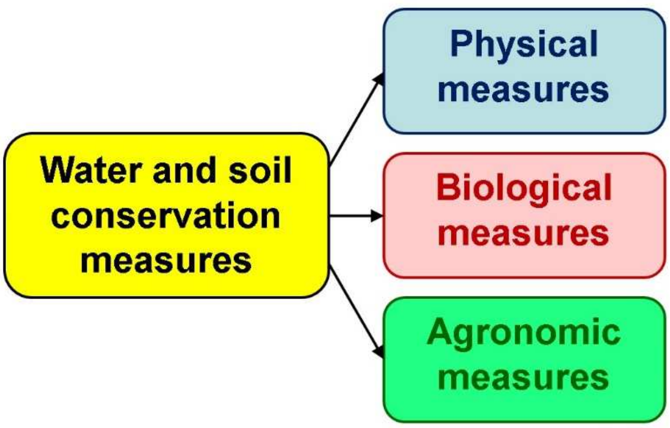

Figure 2 The three measures of water and soil conservation

In this ALRMS project, the engineers focus on the physical and biological measures to evaluate and determine the most sustainable method for the construction of the SDP. Most of the sustainability indicators, including safety management, environmental protection, ecological conversation, reliability, and durability [8], are taken into consideration during the design stage of the SDP. The engineers take three methods for evaluation to determine the most sustainable one and be applied to use in the depot of the ALRMS project.

Two SDPs are designed in the depot zone of the ALRMS project for the temporary storage of soils and debris, which are coming out along with raining through the slope area. Figure 3 shows the location od the two SDPs in the depot zone.

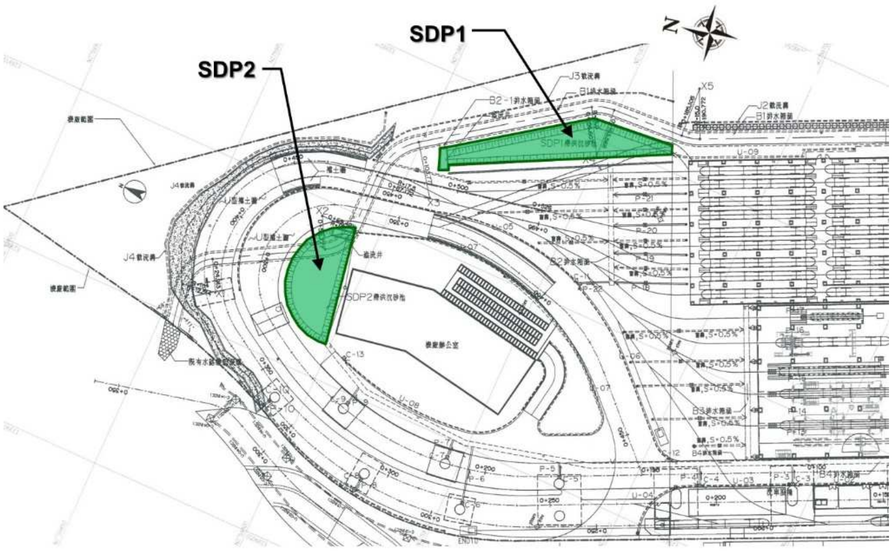

Figure 3 The location of two SDPs in the depot zone of the ALRMS project

DESCRIPTION FOR THE CONSTRUCTION METHODS

There are three options of different types of structure forms were evaluated for SDP design and construction listed as follows:

1. Option 1: The Reinforcing Concrete (RC) structure.
2. Option 2: The gabion structure.
3. Option 3: The shotcrete structure with Soil Nail (SN) anchors.

The following sections discuss the details of the evaluation for these three methods.

Option 1: The Reinforcing Concrete (RC) structure

The construction processes for the RC structure of the SDP are listed as follows:

- Excavation for the pond.
- Placement of the Plain Concrete (PC) for the bottom of the pond.
- Rebars installation for the bottom slab of the pond and placement of concrete.
- Rebars installation for the walls of the pond. This step might be divided into several sections.
- Formwork erection for the walls of the ponds and placement of concrete. This step might be divided into several sections, as well.
- Inlet and outlet structures construction.
- Safety guard installation.
- Backfilling the space between the excavated face and the RC walls.

As our awareness, a reinforced concrete structure is a highly reliable option for the evaluation. However, the construction of reinforced concrete members might consume human-made materials, including cement, rebars, steel members, formwork, and others. It might cause an increase in carbon emissions. It also might play some harmful impact to the environment and the ecology. Figure 4 shows a typical RC SDP.

Figure 4 The photo of a typical RC SDP

Option 2: The gabion structure
The second option for the SDPs design is to build it using the gabion structure. The engineers realized that the raw materials of the gabion are the pebbles in 10cm ~ 40cm diameters. Most of these materials came from nature without any human-made process. Therefore, it might serve as a sustainable option for the construction of the SDPs. In addition to the friend protection to the environment, the ecological issue is also taken into consideration. Besides, carbon emissions can be reduced due to the depreciation of concrete usage and the operation of heavy-duty machines. Furthermore, the construction cost might be reduced to a reasonable level.

The construction processes for the gsbion structure of the SDP are listed as follows:
- Excavation for the pond.
- Placement of the gravel for the bottom of the pond.
- Placement of toe structure.
- Erection of the wire mesh cages for the pebbles.
- Installation of the pebbles.
- Repeat the above two procedures up to the top of the SDP.

The constructure procedures are quite simple and much less than the RC structure listed above. The benefits of the gabion structure are summarized as follows [11]:
1. Durability:
   Gabion has a very high resistance to atmospheric corrosion because of the well bonded zinc coating on the wire and their ability to support vegetation growth.
2. Flexibility:
   This feature permits the gabion to settle and deform without failure and loss of efficiency. Specifically, when unstable ground and moving water are encountered.
3. Permeability:
   It provides automatic and easy drainage which eliminates the need for the installation of drainage pipes.

4. Strength:
   Gabions are satisfactory strong that is it is capable of resisting flood force, torrential force, and ice and earth pressure.
5. Economical:
   It is more economical in terms of both material and labor in comparison with other gabion alternatives.
6. Environmentally friendly:
   Recycled materials can be placed into the gabion cage. The gaps in the soil between filling materials allow the plantation to grow over time. Gabion elements are not affected by natural phenomena.

Figure 5 shows the regular assembly of the wire mash cages [11].

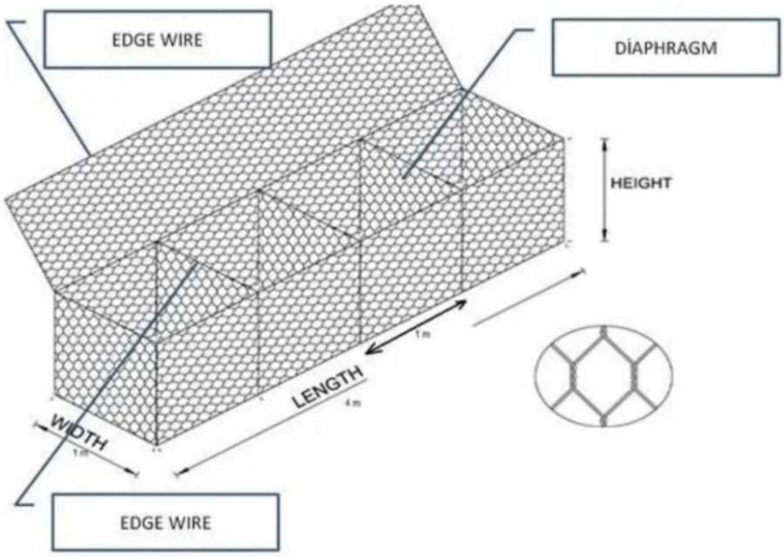

Figure 5 The regular assembly of the wire mash cages [11]

Option 3: The shotcrete structure with Soil Nail (SN) anchors
The shotcrete structure typically combines with the wire mesh and Soil Nail (SN) anchors. The raw materials consumed might less than the RC structures. However, it still uses massive quantities of human-made materials, including the cement and SN anchors.

The construction processes for theshotcrete structure of the SDP are listed as follows:
- Excavation for the pond.
- Placement of the Plain Concrete (PC) for the bottom of the pond.
- Installation of the wire mash in the slope of the SDP.
- Installation of the SN anchors.
- Spraying of the shotcrete materials.

When constructing a shotcrete structure, one of the critical elements to consider is the angle of repose or the angle at which the terrain is stable or able to support itself, and which is determined mainly by the size, shape, and composition of the soil´s particles [12]. Figure 6 shows the appearances of the shotcrete structure slopes in different stages.

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Figure 6 The appearances of the shotcrete structure slopes in different stages: (a)installation of wire meshes and SN anchors, (b) first layer spraying of shotcrete, and (c) finish of final shotcrete slope surface

For the shotcrete structure slope, the stablility analysis is necessary to be performed to ensure the safety of the slope. The following formula is offenly used to check the safety factor of the slope stability:

$$F.S. = (C_a + \gamma\ H \cos\beta \tan\phi) / \gamma\ H \sin\beta \qquad (1)$$

Where:

- F.S.: safety factor, it is required to more than 2 for permanent slope.
- C_a: Soil cohesion
- γ: Soil density
- H: Height of the slope
- β: Slope angle
- ϕ: Angle of friction

In this project, the height of the SDPs is 4 meters. The required slope angle is calculated to be 24°. Thus, a larger area is necessary for the arrangement of the SDPs zone.

EVALUATION AND DETERMINATION

For evaluation and determination on the above stated three methods, the critical sustainability indicators are compared and discussed, as shown in table 1. In Table 1, each evaluation is marked as 1 to 5 points. Higher points represent high performance for evaluation. The total points obtained by the summation of each evaluation item and listed in the "Summarization" row of Table 1. The highest calculation result is the final determination for the selection of structure type for the SDPs design and construction.

Table 1. Comparison table for the three methods of SDPs construction

Evaluation items	RC	Gabion	Shotcrete
Safety and risk mitigation	5	5	3
Reliability	5	5	4
Environment protection	2	5	4
Ecological conservation	2	5	4
Durability	5	5	4
Landscape	3	5	2
Construction Duration	3	4	5
Cost	4	4	5
Humanity	4	5	4

Creatibility	4	4	4
Summarization	**37**	**47**	**39**

The results shown in Table 1 that indicates the gabion structure, 47 points, is the highest scores in the comparison. In other words, the gabion structure is the most sustainable and environmentally friendly selection for the design and construction of SDPs.

CONSTRUCTION OF GABION STRUCTURE

The gabion structure is assembled by the wire mesh cages containing the pebbles and erected layer by layer with the stair style. Table 2 listed the main properties of the wire mesh cages [11].

Table 2. The main properties of the wire mesh cages [11]

Raw materials	**Gabion wire mesh properties**		
Technical properties	**Unit**	**Descriptions**	**Tolerances**
Mesh	mm	50*70, 60*80, and 100*120	
Maximum wire thickness	mm	2 ~ 5	0.05
Amount of covering	Gr/m^2	30 ~ 300	5
Tensile strength	MPa	350 ~ 2000	2
Elongation 25cm long)		10 %	
Plastic coating strength	Turns	5	Shall not break or creak

Even though the use of concrete couldn't prevent for construction of the gabion structure, engineers tried to minimize the quantity for the retaining and stability of the soils. A toe structure to retain the gabion cages is designed to serve as the basement of the gabion structure [13]

Figure 7 and Figure 8 show the drawings of the SDP1 and SDP2, respectively.

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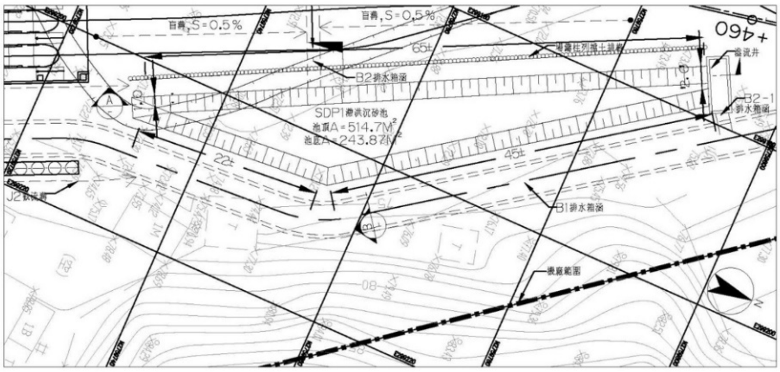

Plan view of SDP1

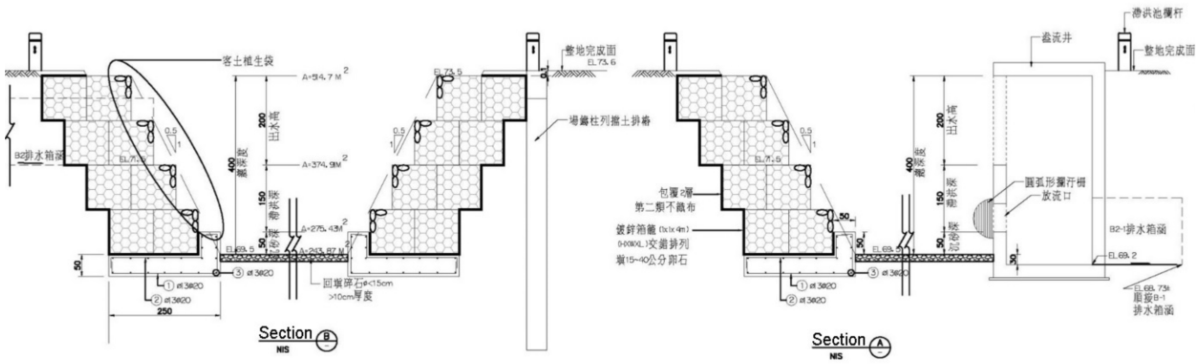

Figure 7 The plan and sections views of SDP1

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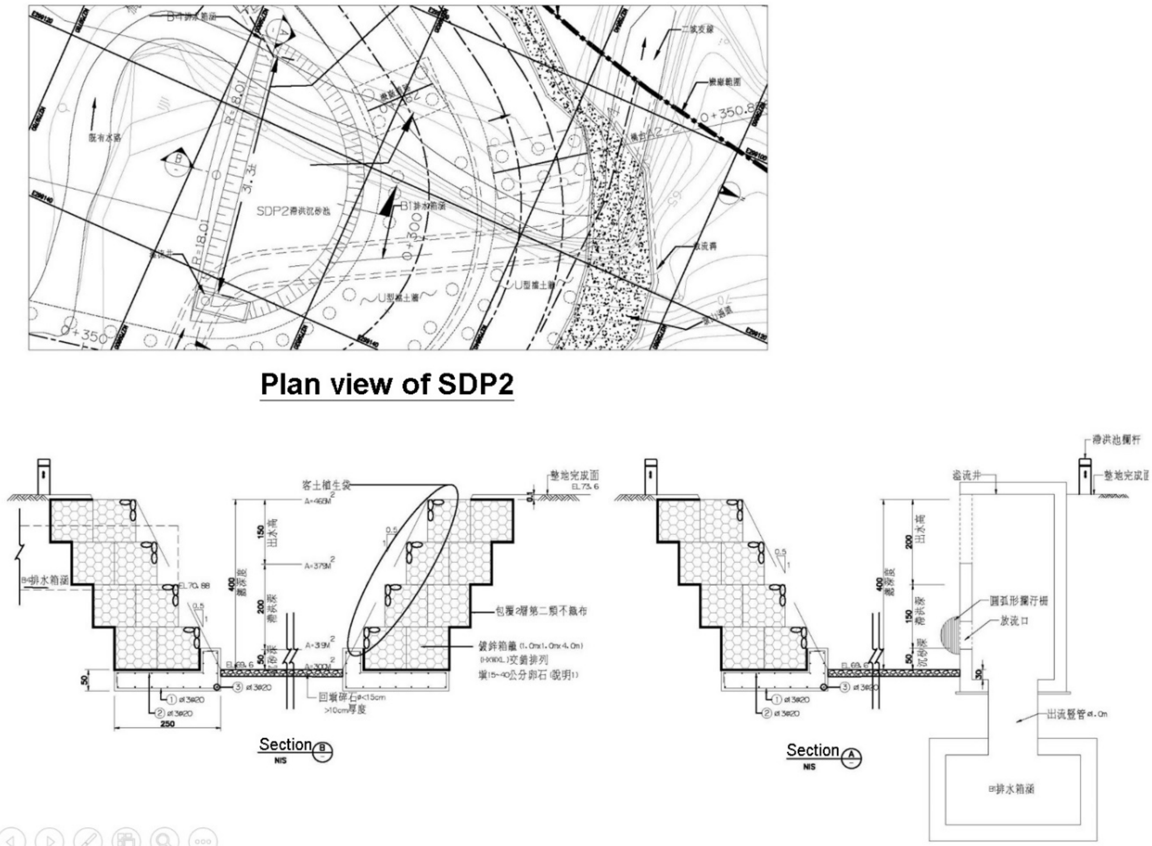

Figure 8 The plan and sections views of SDP2

Following the indication of the above drawings, the site engineers making their efforts for the construction work and estimating to complete the SDPs by the end of October 2020.

Figure 9 shows the work processes of the gabion structure.

Figure 9 The work processes of the gabion structure: (a) excavation for the pond, (b)&(c) installation for wire mesh boxes, and (d) filling of the gravels

CONCLUSION

By application of the gabion structure for the Stormwater and Deposit Ponds (SDPs) design and construction of the Ankeng Light Rail MRT System (ALRMS), it could significantly reduce the use of cement, rebar, formworks, and other materials which are produced by the human. Therefore, it might serve as a sustainable option for the construction of the SDPs. In addition to the friend protection to the environment, the ecological issue is also taken into consideration. Besides, carbon emissions can be reduced due to the depreciation of concrete usage and the operation of heavy-duty machines. Furthermore, the construction cost might be reduced to a reasonable level. This experience could be served as a valuable reference for the development of other similar infrastructure projects.

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