RESEARCH ON EVALUATION METHODOLOGY OF APPROPRIATE TECHNOLOGY FOR INFRASTRUCTURE PROJECTS WITH ODA

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Abstract. While Japan has implemented many infrastructure projects with its ODA, the technologies of Japan cannot directly be applied in many cases to the environment of developing countries where natural conditions, local engineering circumstances, maintenance capacity, etc. are different. In each of the countries, it is necessary to devise technology suitable to the uniqueness of its own environment that are different from Japan (hereinafter "appropriate technology"). However, this situation has not been fully understood in Japan, and appropriate technology devised so far have not been properly evaluated. Therefore, the experience and lessons learned haven't been fully reflected to new projects.

In this research, a case study is conducted on Japanese ODA's infrastructure projects in which appropriate technology was applied. Risks associated with its application are analyzed from the perspective of both the donors and host countries, and a new approach to the evaluation methodology on the technology is examined. In addition, needs for sharing / systematizing the knowledge of the appropriate technology and for mainstreaming the activities in education and research areas on the theme is discussed.

Keywords: ODA, infrastructure projects, appropriate technology, evaluation methodology, mainstream

1. NTRODUCTION

In Japan, infrastructure has been developed under ample finances, advanced technologies. and sophisticated production systems. The technologies have been manualized by incorporating the latest knowledge at the time and their application has been institutionalized. Japan has built a lot of infrastructure not only domestically but also overseas with ODA. However, Japanese technology is not always optimal in host countries where natural environment, construction circumstance, financial situation, and sustainability of maintenance are different. Technology that is most effective for the environment of the locality is required. It is defined as " appropriate technology ".

While appropriate technology has been applied to many of Japan's ODA projects so far, current situation is that its methods and effects have not been fully understood, commonly shared nor integrated. The effects and usefulness of appropriate technology are not fully recognized so much as the standard technology, which is defined as prevalent technology based on the manuals of Japan. This research aims to clarify that appropriate technology contributes to the betterment of ODA infrastructure projects, to propose its evaluation method and to suggest needs for its information sharing and integration. The mainstreaming of appropriate technology is an urgent issue.

Table 1. Projects in which appropriate technologies were applied in Japan's ODA for infrastructure

	Technology applied	Japan's ODA
1	Causeways across rivers without dikes	Examples exist in grant aid projects in Nepal and Cambodia. [1~5]
2	Multi purpose sabo dams	There are examples in Yen loan projects in Indonesia. [6]
3	Permanent structures with gabions [7]	Many examples exist in grant, Yen loan and technical cooperation in various countries.
4	Simple conc. plants in remote areas	There are examples in Yen loan projects in Indonesia. [8]
5	Construction of double tube wells	There is an examples in technical cooperation in Indonesia. [9]
6	Flood control on natural rivers	FS was conducted in Fiji in 2016,but implementation has not been commenced . [10]
7	Irrigation weirs on unstable rivers in Pakistan [11]	Design with Japan's manual was judged infeasible due to difficulty of maintenance. Structure was built by the host country with material for local design supplied by ODA .
8	Problem soils in road construction	Disperse soil in Cambodia and expansion soil in East Africa were dealt with by grant aid projects. JICA has created a handbook on the problem soils. [12]
9	Measures for rutted asphalt roads	The issue was addressed in many grant aid projects. JICA has created a handbook. [13]
10	Integral abutment bridge	It was applied in a grant aid project in Cambodia. It has the effect of reducing costs. The design procedure is shown in the 2012 Road Bridge Manual of Japan. [13, 14]
11	Labor Based Technology, LBT (labor-based technology)	Technical cooperation on road construction with LBT was provided to the Appropriate Technology Training Institute in Tanzania from 2006 to 2011. LBT has been adopted in many developing countries. Technical manuals have been prepared by the ILO and the World Road Association (PIARC). [15]
12	Concrete production technology under environment different from Japan	Research was conducted on concrete production technology under different conditions from Japan such as Asia and Africa. The above 4 is a typical example. [16, 17]

Figure 1. Damages of flood plain roads and bridges of rivers without dikes

By Mr. T. Kurihara

Figure 2. Soured riverbeds at bridges

Figure 3. Causeway / overflow bridge by Japan's ODA/NGO

2. CASE STUDY ON APPROPRIATE TECHNOLOGY APPLIED TO JAPAN'S ODA

Table 1 shows typical Japan's ODA infrastructure projects in which appropriate technology was applied. Appropriate technology is often used in the fields of rivers, roads, and concrete production. Among these, there are certain technologies for which guidelines suitable for the local environments have already been prepared. Except for these, the following five projects, 1 to 5 in the table, are selected for case study. Their usefulness and risks are examined in the following sections.

2.1. Causeways and overflow bridges across flood plains and rivers without dikes

Most of rivers are natural without dikes in host countries. Length of bridges are minimum and embanked approach roads protruding to river channels are constructed. Across flood plains of large rivers, roads are elevated with embankment. During rainy season, such road structures interfere flood

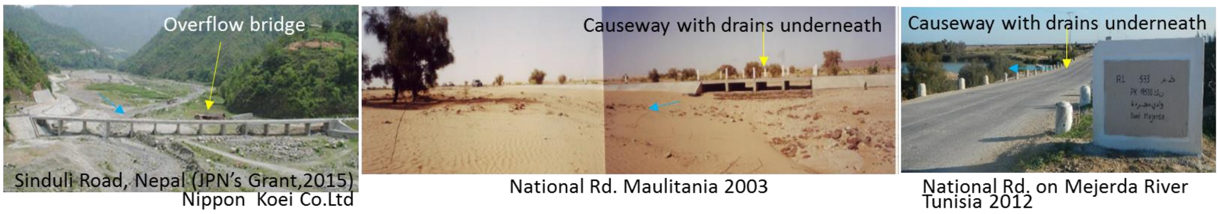


Figure 4. Overflow bridge by Japan's ODA and causeways in host countries

Figure 5. Multipurpose sabo dams in Indonesia

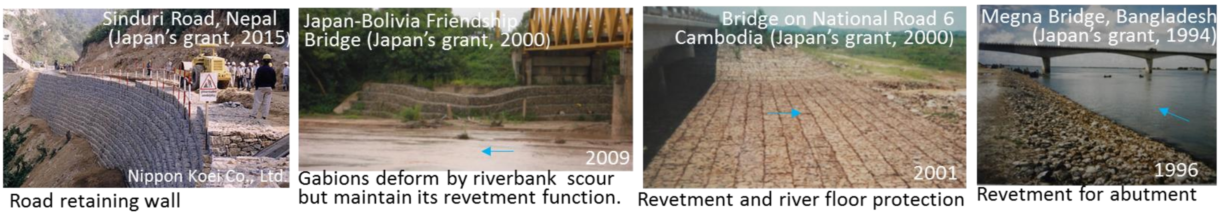


Figure 6. Structures with gabions in host countries with Japan's ODA

flow. As a result, embankment of approach roads is hit by flood and soured. In flood plains, flood flows over embankment. As a result, pavement is damaged and embankment is eroded (Fig. 1). River beds are scoured due to increased flow velocity passing under bridges, leaving the piers and abutments unstable (Fig. 2). In order to minimize these problems, bridge length should be increased to insure sufficient flow capacity during flood events. However, this leads to increase of project cost which overwhelms the budget [1].

For solution, causeways and overflow bridges are adopted in Japan's grant aid projects. These structures allow overflow of floods. Fig. 3 and 4 show examples of a Japan's ODA project in Nepal. Causeways and overflow bridges have been built in various countries by NGOs, donors and host countries' own budget (Fig. 3 and 4). These structures are practical in solving the problems in natural rivers without dikes and effective in cost reduction. [2 ~ 5].

2.2. Multipurpose sabo dams for regional development

In Java Is., Indonesia, Urgent Mt. Merapi Disaster Reduction Project (hereinafter, Mt. Merapi Project) was implemented with Yen loan through 2006-2011. This included construction of twenty three sabo dams. During the two phases of disaster reduction projects that preceded through 1985-2001, it turned out that there were also needs for infrastructure for regional development such as bridges and irrigation weirs. However, it was difficult to build these infrastructures for each of the purposes in terms of budget.

For solution, multipurpose sabo dams were constructed with four bridge type dams that allow vehicles pass over crests, and nine irrigation weir type dams with intake gates upstream, and irrigation canals downstream (Fig. 5) Multipurpose sabo dams had been constructed with Indonesian government's budget (Fig. 5, extreme right) and were adopted by Japan's ODA [6].

Figure 7. Various kinds of structures with gabions in host countries

Figure 8. Concrete production and quality control in remote mountains

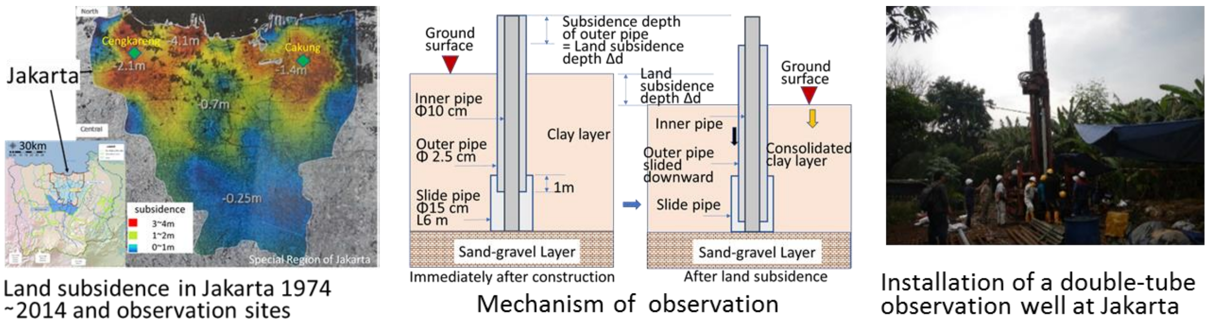


Figure 9. Land subsidence observation in Jakarta with double tube wells

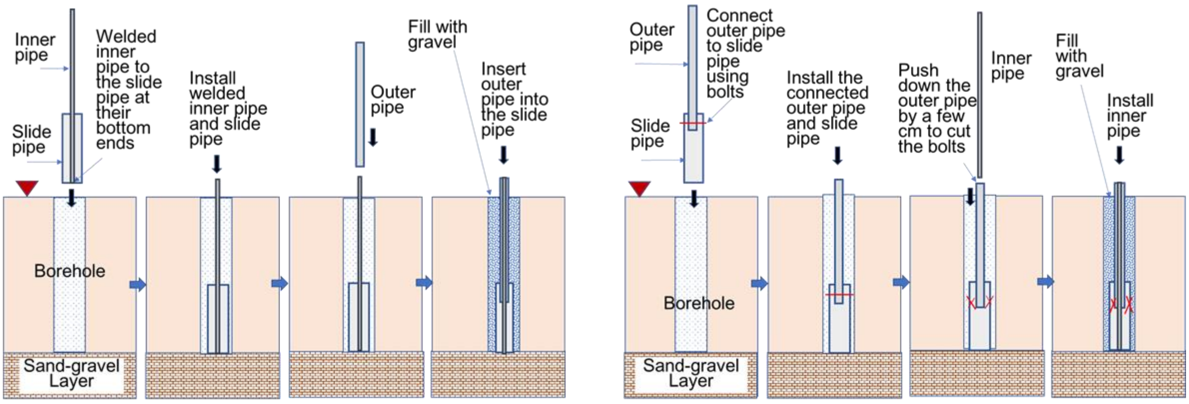
2.3. Civil engineering structures with gabions

Infrastructure must be constructed with materials that has no difficulty in procurement, and sustainable maintenance be secured. However, depending on construction sites, it is difficult to procure factory products such as concrete blocks, which leads to increase of cost in and difficulty in maintenance

For solution, gabions are used in many Japan's ODA projects (Fig. 6 and 7). Materials, steel wire and cobblestones, are less expensive and can be procured locally. Maintenance even by local residents is possible without advanced technology. While its structural reliability is not regarded sufficient in Japan [18], it is widely used in host countries and is sustainable/practical under local construction circumstances (Fig. 7) [7].

2.4. Simple concrete plant in remote mountains and its quality control method

In the fore-mentioned Mt. Merapi Project, all the twenty three dam sites were located in mountains where access of ready mixed concrete transport vehicles was difficult. However, it was not possible to build a concrete manufacturing plant at each dam site in terms of cost. Since good quality of aggregate was obtained on the riverbed at every site, the particle size was adjusted by sieving on the riverbed, and concrete materials were mixed in a steel box beside flames. All these works were done only by excavators. The produced concrete was put into flames by simply moving the arm of the excavator (Fig. 8) [8]. All the work was carried out on the construction sites.



Conventional installation method practiced in Japan — New installation method proposed by a local contractor

Figure 10. Installation methods of double-tube wells for land subsidence in Jakarta

Regarding quality control of concrete, it was difficult to measure sand surface water content with JIS standard at all twenty three sites because of its high cost of laboratory kits and uncertain quality of local technicians. For solution, the sand was heated on a pan to dry its surface, and the difference in weight before and after heating was measured.

Sieves and steel boxes were manufactured at a local ironwork. Kitchen utilities were used as surface water measurement equipment and these were purchased at local stores.

2-5 Construction method of double-tube wells for land subsidence observation

In Jakarta, land subsidence progresses due to excessive use of groundwater. With the technical cooperation by Japan's ODA in 2019, two double-tube wells were installed for land subsidence observation (Fig. 9). A local contractor conducted installation work by the method of "binding the outer pipe to the slide pipe with bolts", which was commonly practiced in Japan. But the bolts were broken during installation and the work was suspended (Fig.10, left).

While in the trouble, "welding inner pipe with slide pipe" method was proposed by the local contractor (Fig.10, right). The installation work resumed with the proposed method and was completed without any trouble. A method that could be implemented locally was created by a local contractor [9].

3. ISSUES IN APPLICATION OF TECNOLOGY TO MINIMIZE` RISKS

Through the analysis of the five projects, it has been found that project cost may rise and maintenance become difficult if Japanese technology is applied without modification to local environment. It is necessary to assess the risks that may arise by the technologies to be applied. Our analysis extracted six risk assessment axes: ① Response to natural conditions, ② Response to construction circumstances, ③ Reduction of project costs, ④ Sustainability of maintenance, ⑤ Utilization of local resources, and ⑥ Utilization of local technology. These six axes are related to each other.

4. CONTRIBUTION OF APPROPRIATE TECHOLOGY TO RISK REDUCTION

5 projects are qualitatively evaluated with the six risk assessment axes (Table 2). Appropriate technologies and corresponding standard technologies are compared. If the appropriate technology is more effective than the standard technology for risk reduction, any of the corresponding axes 1~4 is marked with ○. Any of the axes 5-6 is marked with ○ when it is applies. The technologies applied to the five projects show their superiority to standard technology in risk reduction.

Table 2. Contribution of appropriate technology for risk reduction

Appropriate technology vs Standard technology	①Response to natural conditions	②Response to construction circumstances	③Reduction of project costs	④Sustainability of maintenance	⑤Utilization of local resources	⑥Utilization of local technology
(1) Causeway vs Bridge	○		○			○
(2) Multipurpose sabo dam vs Individual construction of sabo dam, bridge and wier			○			○
(3) Gabion vs Conc. block		○	○	○	○	○
(4) Steel box vs Conc. plant		○	○		○	
(5) (Double tube well) Locally invented method vs Prevalent method of Japan		○		○	○	○

Table 3. Difference in risk awareness between the donor and host countries

Projects	Standard Technology / Appropriate Technology		Donors' View		Host country (user) 's View
(1) Causeway	Bridge	A	Complies with Japanese design standards. Risk of quality, safety, and function is less.	C	Maintenance is difficult in rivers without dikes due to unstable channels. High construction cost.
	Causeway	C	There is no design standard. There are risks of downstream scouring, and reduced user safety / traffic suspension during the events of flood.	A	Can be measures for natural / unstable rivers. Construction cost is small. Cost and risks (downstream scouring, deterioration of safety and traffic function during floods) are balanced.
(2) Multipurpose sabo dam	Individual construction of sabo dams, bridges and weirs	A	Complies with Japanese design standards. Less risk of safety and functions.	C	Facilities need to be constructed for each purpose. Construction cost is high.
	Multipurpose sabo dam	C	There is no design standard. There is risk of reduced user safety/traffic suspension in events of flood, and blockage of the intake gates with sediment upstream of dams.	A	One facility is multifunctional and construction cost is less. Meets multiple needs at reduced cost. Cost and risks (reduced users' safety / traffic suspension during floods and blockage of intake gates with sediment) are balanced.
(3) Gabion	Conc. block	A	There are design standards. It is the permanent structure. Quality risk is small.	C	Construction and maintenance costs increase.
	Gabion	B	There is no design standard as a permanent structure. Generally used as emergency structures. Risk exists in durability and strength.	A	Construction cost is low by using local resources. Easy to maintain. Cost and risks (less strength and durability) are balanced.
(4) Steel box	Conc. plant	A	Prevalent method in Japan. Quality control is assured. Supply in quantities is possible.	C	Installation cost of plants is high. Inefficient for sites dispersed in mountains.
	Simple concrete plant with steel boxes and excavators	C	No case in Japan. There is a risk in concrete quality.	A	Many construction sites are dispersed in the mountains, but the cost is low because the aggregates are available at each site. The cost and risk (quality control) are well balanced.
(5) Double Tube	Bolts binding of slide pipe and outer pipe	A	Prevalent method in Japan.	B	Difficult for local contractors. Risk is more
	Welding slide pipe with inner pipe	A	No case in Japan but possible with local resources. Low risk of implementation. Sustainable.	A	Construction using local resources is possible. Risk is less. Sustainable.

Score	Donor`s viewpoint: design standards, prevalence in Japan	Host country's viewpoint: assessment axes ① to ④ as users
A	Design standards exist. Many examples exist in Japan	Can correspond to the assessment axes ① to ④
B	Design standards as temporary structures or examples exist	Can correspond to a part to the assessment axes ① to ④
C	No design standards. Few examples in Japan	Can hardly correspond to to the assessment axes ① to ④

Table 4. Proposal of a new project evaluation methodology

DAC Evaluation items	Criteria	Axes that contribute to DAC criteria	Cause way	Multi purpose sabo dam	Gabion	Simple conc. plant	Double tube well
1. Validity	Suited to priorities and policies of the target group, recipient and donor?	①~④	○	○	○	○	○
2. Effectiveness	A measure of the extent to which an aid activity attains its objectives	①~④	○	○	○		
3. Efficiency	The aid uses the least costly resources possible to achieve the desired results?	③	○	○	○	○	
4. Impact	Positive and negative changes produced by a development intervention	①~④	○	○	○	○	○
5. Sustainability	Are benefits of activity likely to continue after donor funding withdrawn?	④	○	○	○	○	○

Assessment axis : ① Response to natural conditions ② Response to construction circumstances ③ Reduction of project costs ④ Sustainability of maintenance

New evaluation item	Criteria	Reason
6. Appropriateness of technology from user's view-point	Has appropriate technology been applied to natural conditions, construction circumstances, reduction of project costs, and ensuring sustainability of maintenance?	Technology is an important factor for manifestation of project effects. By clarifying the contribution of technology to the effects and feeding back the results to new projects, the quality of ODA can be further enhanced.

5. DIFFERENCE IN RISK AWARENESS BETWEEN DONORS AND HOSTCOUNRTIES

Difference in risk awareness between the donor and host countries is analyzed (Table 3). 5 projects are evaluated with ABC in ascending order of risks assuming the donor's viewpoint stands on design standard / prevalence in Japan and host countries (users) stand on assessment axes ①~④. It has turned out that difference in risk awareness exists between the two. This indicates that the donor needs to understand the local situation and customize their standard technology accordingly.

6. PROPOSAL OF A NEW PROJECT EVALUATION METHODOLOGY

JICA evaluates projects in accordance with DAC evaluation items; validity, effectiveness, efficiency, impact, and sustainability [19, 20]. However, DAC has no item that evaluates the role technology plays in the manifestation of projects' effects. To find whether technologies applied to the 5 projects contribute to the improvement of any of the DAC evaluation items, their relationship is checked quantitatively and tabulated (Table 4). The analysis shows that the appropriate technology contributes to betterment of DAC evaluation items. To improve the quality of ODA of infrastructure, it is important to evaluate the contribution of technology and to feed back the lessons learned to new projects. Therefore, it is proposed to add "appropriateness of technology from the user's viewpoint "as the sixth evaluation item.

7. MAINSTREAMING APPROPRIATE TECHNOLOGY IN ODA PROJECTS

Appropriate technology has been applied to many Japan's ODA infrastructure projects. For the betterment of their quality, following activities are proposed

1) Design guidelines are made about themes not found in standard technology, such as causeways / over flow bridges, flood control in natural rivers, steep slope retaining wall with gabions, etc.
2) Knowledge on appropriate technologies accumulated in organizations, engineers and researchers is shared and integrated. For this purpose, papers are collected and organized.
3) Interdisciplinary merging such as bridge engineering and river engineering, engineering and social science, is enhanced.
4) Research and education on civil engineering technologies appropriate for host countries / users is mainstreamed.

Challenges of JSCE / VFCEA are to

1) Coordinate the relevant organizations on the said activities and set up working groups / forums,
2) Advise donors as JICA or DAC to incorporate technical perspective into their evaluation on the infrastructure projects, and
3) Assist donors to prepare technical guidelines.

8. DISCUSSION ON THE ESSENSE OF APPROPRIATE TECHNOLOGY

In Japan, there are many cases where appropriate technology was applied and existing standards have been revised.

Some of these are summarized below.

1) Construction of 1.5 lane roads in Kochi Prefecture: In areas with low traffic volume, roads are designed according to the actual condition, regardless of the standard design of 2 lanes [21].
2) Tsunami countermeasures after Great East Japan Earthquake 2011: In the tsunami countermeasures before the earthquake, disaster prevention measures depended on coastal structures. In new countermeasures after the earthquake, Level 2 tsunami, with low frequency of occurrence in hundreds to thousands of years with enormous damage, has been newly incorporated. Emphasis is placed on the assured evacuation of residents [22].
3) Geological risk management: Since geological phenomena are difficult to foresee, it was a kind of "standard" method that conducts minimum geological investigations, prepares a basic design, and responds to emerging risks by changing the design during construction [23]. However, due to the significant increase in construction costs and large-scale accidents during construction, it has become necessary to manage geological risks properly. Currently, the Ministry of Land, Infrastructure, Transport and Tourism has begun to develop a revised "standard".

From the perspective of risk management, a feature of these projects is that risks are identified and countermeasures different from the standard are applied. As a result, the project cost is reduced and the project effect is improved. Appropriate technology is a risk management that examines the risks peculiar to the site and the tolerance of the society to the risks. Adopting appropriate technology leads to amendment of manuals of standard technology.

9. IMPLICATION OF APPROPRIATE TECHNOLOGY

1) Appropriate technology does not mean an outdated nor cheap construction method. It is the creation of sustainable function suitable for the local environment [24]. Technology is the ability to find issues and solve problems. It is not whether advanced technology is used.
2) Even if the economy and society of the country develops and technology advances, the importance of pursuing function that is consistent with the nature and society of the locality shall still remain.
3) Appropriate technology also exists in Japan. Adoption of appropriate technology means optimization of the technology. It is a risk management that achieves the purpose of the project in efficient ways.

10. CONCLUSION

The technology to be applied to ODA infrastructure projects has been discussed.

1) In ODA infrastructure development, there are constraints from ① natural conditions, ② construction circumstances, ③ project costs, and ④ sustainability of maintenance. The technologies applied to the 5 projects were effective to release risks caused by the constraints. It is important to manage risks from user's perspective of ①〜④.
2) Appropriate technology contributes to the betterment of DAC evaluation items. Regarding the ODA infrastructure projects, it is proposed to add "appropriateness of technology from the user's viewpoint" as the sixth evaluation item.
3) It is necessary to mainstream appropriate technology. For its achievement, the role of VFCEA and JSCE is important.

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