Chapter 5

Spot Improvement of Rural Roads Using a Local Resource-Based Approach: Case Studies from Asia and Africa

Yoshinori Fukubayashi and Makoto Kimura

Additional information is available at the end of the chapter

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Abstract

Rural roads in developing countries continue to be in poor condition despite multiple interventions. To provide access to markets, hospitals and schools for rural communities, capacity building has been conducted, enabling rural communities to participate in road projects. This process has included the transfer of Do-nou technology, which is appropriate for spot improvement using a local resource-based approach. The goal has been to transform the road projects implemented through community initiatives, maximizing their effectiveness and practicality, and thus improving the conditions of rural roads. Case studies have been conducted in Myanmar, the Philippines and Kenya. They demonstrate that spot improvement and the use of locally available materials can provide socioeconomic benefits to communities. Designs based on this approach have been developed for the construction of base courses, retaining walls and causeways. These designs can be applied over wide areas and modified to reflect the unique conditions of each project area. The experience gained in community mobilization and stakeholder involvement, which is essential in the proposed approach, can serve as a guide when applying the approach in new areas.

Keywords: rural roads, accessibility, spot improvement, local resource-based approach, community initiatives, capacity building, developing countries

1. Introduction

In this chapter, we discuss one of the key measures for improving rural roads and extending socioeconomic benefits to rural communities in developing countries. The key challenge is the improvement of rural roads under circumstances in which financial and technical constraints dominate.

Spot improvement was conceived as one of the solutions. This method involves a local resource-based approach in which community initiatives are transformed into practical interventions. Specifically, Do-nou technology [1], which is a Japanese term for a type of soil bag, became recognized as a means of building unpaved roads [2], retaining walls, and other road structures using the geotextiles available in developing countries. Only simple skills and labour are required, which fosters community initiatives for the improvement of rural roads. This approach has been introduced in both Asia and Africa.

Figure 1 shows a schematic view of the road network in a developing country. Road classification schemes vary from one country to another, but in general, road networks consist of trunk/regional, rural, rural access and unclassified roads. The trunk/regional roads are grouped as major roads, while the remainders are classified as rural.

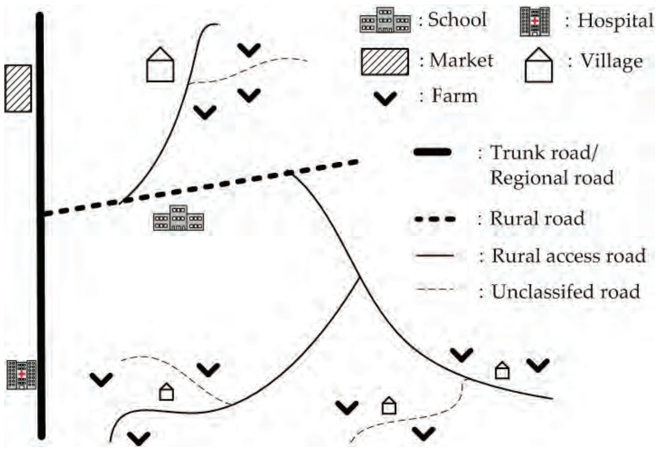

Figure 1. Schematic view of road network.

The road networks in developing countries have been developed through a combination of local government institutes efforts and assistance from donor agencies. Interventions have prioritized the major road networks, given their capacity to accelerate the growth of the market economy, the scale of their impact, and the efficiency of investment. Because the limited financial resources are mainly given to building, rehabilitating, and maintaining major roads, the rural roads in developing countries remain in poor condition.

While rural roads carry only low volumes of traffic, they are vital lifelines for people who live along them, offering access to markets, schools and hospitals. The inaccessibility of many rural roads isolates the local population from socioeconomic benefits (**Figure 2**). Thus, the poor state of rural roads can be identified as a significant cause of poverty in rural areas [3].

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Figure 2. Ambulance stuck on an unpaved road in Papua New Guinea.

On 25 September 2015, the 2030 Agenda for Sustainable Development called Transforming our World was adopted by the United Nations Sustainable Development Summit [4]. The new targets that were set were referred as to Sustainable Development Goals (SDGs) and had the aim of ensuring that no one would be left behind. The ninth goal was to build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation. Research initiatives and case studies on ways of improving rural roads through the development of appropriate technologies and by equipping rural communities to use them are in line with this international development goal.

In this chapter, we present case studies of capacity building to enable rural communities to tackle the rural road problem through spot improvement using local resource-based approaches. We discuss the following issues:

1. The conventional approach to rural road improvement and its limitations;
2. The characteristics of the proposed local resource-based approach to rural road improvement;
3. Case studies from Asia and Africa;
4. Lessons to be learned from the case studies.

2. Conventional approach to rural road improvement and its limitations

2.1. Labour-based technology (LBT) favours government institutions

Since the 1970s, a number of projects have been conducted with the purpose of improving the capacities of local government institutions, enabling them to deliver rural infrastructure services effectively in developing countries [5]. Labour-based technology (LBT) has been mainstreamed in these projects. The key to this approach is the use of locally available resources such as labour, tools, and light equipment, combined with good workmanship and high quality standards. The definition of LBT varies from one country to another. However, from the view point of the authors, the following definition of LBT accurately describes its real implementations. LBT optimises the use of productive labour and complements the use of labour with the equipment that is essential to meet specified technical and engineering standards [6]. LBT is more appropriate for road projects that are executed by local government institutions, rather than those achieved through community initiatives.

2.1.1. Design standards

In LBT projects, unpaved roads are designed in accordance with the geometric and structural standards specified in the current design manual for low-volume gravel roads, and these are prepared by local government institutions [7, 8]. To comply with these standards, it is necessary to procure specified materials such as gravel with an appropriate grain size contributions, plasticity, and CBR value. It is also necessary to use equipment that can meet the specified technical and engineering standards. Tractors, trucks, and compact rollers are needed for hauling gravel, watering, and compaction (**Figure 3**).

To make this equipment available, LBT requires contractors who are capable of owning, or at least operating and maintaining it, while the communities living along the road can find only employment as labours.

While such a design policy ensures that the roads selected for the projects are of high quality and meet the standards, the unit cost is increased. As a result, the length of the improved road that can be achieved is limited.

Figure 3. Road rehabilitation work in Timor Leste, using the equipment required for LBT.

2.1.2. Basic rule for available road budget allocation

Any roadwork programme conducted by a local government institution has as its basic rule the protection of earlier investment. The available funds are therefore allocated firstly to routine maintenance, secondly to periodical maintenance and thirdly to rehabilitation [5]. In the case of a road on which some sections have fallen into total disrepair, it may be judged that there is no point in providing further maintenance. Instead, the appropriate approach would be to undertake extensive reconstruction or rehabilitation works before the road is once again included in the maintenance scheme.

On this basis, and due to the limited budgets available, badly degraded rural roads with lower traffic volumes may receive no intervention over long-time periods (**Figure 4**).

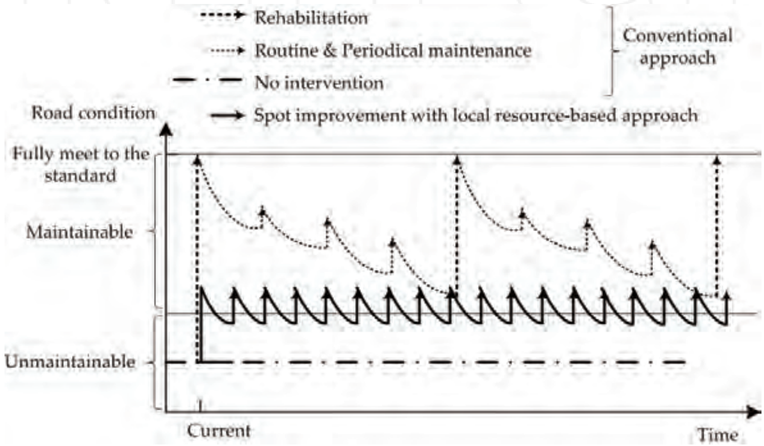

Figure 4. Road condition and interventions over time.

2.2. Limitations of the conventional approach

In Kenya, where the LBT approach has been applied to rural road projects since the 1970s, 31% of classified roads and 72% of unclassified roads were evaluated as being in poor condition in surveys conducted between 2007 and 2009 [9]. It is claimed that the government needs urgent additional funding to restore the network to a maintainable condition. However, it is difficult to envisage the government allocating such additional funding, considering the history of LBT in Kenya. A new approach is therefore needed to improve Kenya's rural road network.

Spot improvement using a local resource-based approach, which can be applied to road works through community initiatives, is considered be one of the measures that could be used to improve rural roads, in tandem with government road projects. In contrast with LBT, the proposed approach uses community initiatives to undertake practical road projects, thus improving access to markets and social services and accelerating development.

3. Spot improvement using a local resource-based approach

3.1. Objectives

If road projects conducted through community initiatives can achieve satisfactory quality, rural roads that government institutes cannot improve because of budget limitations can be improved instead by communities themselves, or by collaboration between the local government and community.

In such road projects, the community itself must manage the selection and procurement of base materials and the compaction of the base and wearing course materials. At this point, geotextile technology can be applied to reinforce the shear strength of the soil material through manual compaction. This method has been applied to rural road infrastructure.

The technology should use local resources and be labour intensive, and simple, enabling community members to perform all aspects of the improvement work. Thus, spot improvement methods using local resources have been developed to promote community participation. Specifically, Do-nou technology has been applied to rural road infrastructure.

3.2. Methods and implementation

Matsuoka and Liu [1] found that quality-controlled soil bags, here called Do-nou, have high-bearing capacities and developed both a theoretical model and a practical formula for calculating their capacities. This theory enabled the authors to identify the plastic bags used for crops, fertilizer, sugar, etc. in rural areas of developing countries to be used as Do-nou bags, thus serving as geotextiles for reinforcing the shear strength of the soil material.

3.2.1. Base course built through manual compaction

3.2.1.1. Structural design

The structural design of a base course consisting of Do-nou is shown in **Figure 5**.

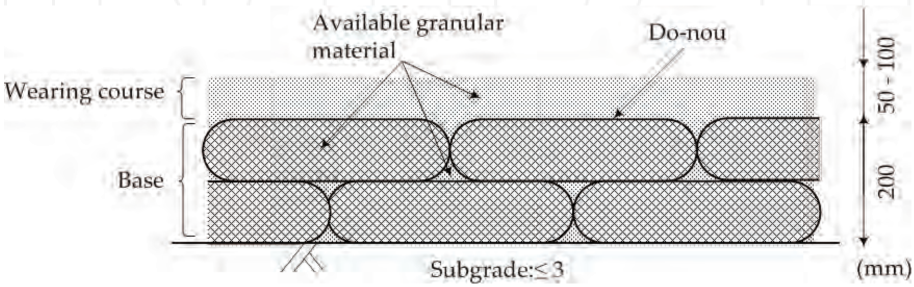

Figure 5. Structural design of road built with Do-nou.

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Figure 6. Practical manual compaction method for community work.

Layers of Do-nou filled with locally available gravel form the base, bearing the traffic load and reducing deformation, and thus protecting the subgrade from excessive stresses. The wearing course in turn prevents the Do-nou from being exposed, whilst providing a smooth and durable road surface. The thickness of the compacted wearing course layer is 50–100 mm, which is appropriate under circumstances in which only manual compaction with hand rammers of small mass is available, and in which the cost of transporting the wearing course material needs to be minimized. This thin wearing course requires frequent but simple maintenance, including filling to restore the gravel lost through erosion due to weather and traffic.

3.2.1.2. Manual compaction

For civil projects initiated and completed by communities in the poor rural areas of developing countries, the most widely available, efficient, and practical compaction method is the use of a hand rammer with a mass of approximately 10 kg and a base area of approximately 0.04 m^2 (for example, a square of 0.2 m per side). Such rammers are dropped from a height of approximately 0.6 m and accelerated manually (**Figure 6**).

When building a base course using Do-nou technology, the confinement of the soil material in bags makes this manual compaction method satisfactory for the base course. The manually compacted Do-nou layer can provide a firm platform for the later compaction of the wearing course.

3.2.1.3. High bearing capacity of Do-nou

The tensile strength of the bags enclosing the soil material increases through this compaction process (**Figure 7a**). The soil inside the bag becomes denser, while the bags themselves become taut (**Figure 7b**). When traffic passes across the road surface, the soil material is subjected to passive shear (**Figure 7c**). The stress conditions are shown in **Figure 7d**. According to Matsuoka and Liu [1], the major principal stress σ_{1f} at failure can be calculated as follows:

$$\sigma_{1f} + \frac{2T}{B} = K_p\left(\sigma_{3f} + \frac{2T}{H}\right) \quad (1)$$

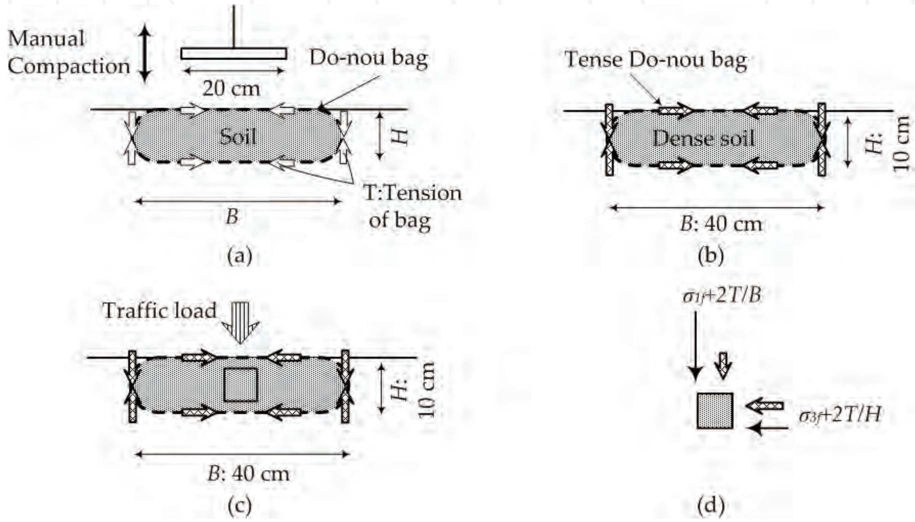

Figure 7. Mechanism that generates the bearing capacity of Do-nou: (a) Do-nou subject to manual compaction; (b) Do-nou after compaction; (c) Do-nou under traffic load; (d) stress condition of the soil material inside Do-nou at passive failure.

Therefore,

$$\sigma_{1f} = \sigma_{3f}K_p + \frac{2T}{B}\left(\frac{B}{H}K_p - 1\right) \quad (2)$$

where T is tensile strength, and B and H are the width and height, respectively, of the Do-nou. $K_p = (1 + \sin \emptyset)/(1 - \sin \emptyset)$ is the lateral earth pressure ratio in the passive state and $\emptyset$ is the internal friction angle of the soil material inside the bag. The bearing capacity of each Do-nou can be calculated by multiplying σ_{1f} times the area of the Do-nou, $B \times L$, where L is the length of the Do-nou.

As the Do-nou undergo compaction, the effective vertical and horizontal stresses on the soil material inside the bags increases. Compared to the loose soil incurred in the case of conventional designs but no compaction with equipment, the shear to which the material inside the Do-nou is subjected is confined. Moreover, the tensile strength T generated in each bag also increases its capacity, as shown by Eq. (2). Thus, by confining the soil in bags, the base course consisting of Do-nou achieves a higher bearing capacity. The bags act as a geotextile, increasing the shear strength of the soil.

Equation (2) shows that the bearing capacity of each Do-nou increases as the tensile strength of the textile that makes up the Do-nou bag increases, and as the ratio of B/H and $K_p = (1 + \sin \emptyset)/(1 - \sin \emptyset)$ becomes larger, where K_p is a positive function of $\emptyset$. Thus, bags with higher tensile strengths and granular soil materials with higher internal friction angles are preferred in Do-nou applications.

3.2.1.4. Do-nou bags

It was found that bags woven from either polypropylene or polyethylene could be utilized. Such bags are widely used in developing countries for crops, sugar, seeds, and fertilizers. Tensile strength tests confirmed that the fabric used in bags designed to hold 25 kg had sufficient ductility and tensile strength to bear traffic loads [2]. Two widely recognized tensile strength criteria are that a bundle of 1000 bags of width 45 cm and length 60 cm should have a mass of more than 45 kg, and that the fabric should have more than 10 woven threads per inch. Used empty bags represent a geotextile resource that is widely available in the rural communities of developing countries, and these can be employed for road intervention using the Do-nou technology.

The procedures introduced to fill and compact the Do-nou mean that each compacted Do-nou reaches a width and length of 40 cm, a thickness of 10 cm, and a mass of about 20 kg. The Do-nou then resembles a boulder in size and weight and is easily to handle. The Do-nou is laid uniformly on the subgrade to form the base course.

3.2.1.5. Gravel

Gravel road design manuals usually specify the base and wearing course material in terms of particle size distribution, strength, and plasticity, taking account of climate factors. The thickness of the base course is specified for each type of material based on the strength of the subgrade and the traffic load over the design lifetime, which is generally 5–10 years. Since Do-nou technology increases the density and bearing capacity, poorly graded and weaker types of gravel with higher plasticity can be used in base courses at the similar thickness specified in the manuals. Material confined within the Do-nou bags can be used to fill the spaces between the laid and compacted Do-nou, as shown in **Figure 5**. The Do-nou approach therefore widens the range of materials that can be used as the base course.

		Do-nou technique application	Design manual in Ethiopia [7]	Design manual in Kenya [8]
Traffic range (number of vehicle per day)		<100	<75	50–150
Envisaged compaction means		Hand rammer with a mass of around 10 kg	Roller with a mass of 5 tons	
Base	Material	Available granular and sandy material & Do-nou bags	Specified gravel • Soaked CBR ≥15 • Swelling ≤1.5% • Plasticity index <12 • Grading coefficient G_c 16–34[b]	Specified gravel • Soaked CBR ≥20 • Plasticity index 5–20 • Well-graded[e]
	Thickness (mm)	200	200	500
Wearing course	Material	Available granular and sandy material[a]	Specified gravel • Maximum grain size 37.5 mm • Soaked CBR ≥15 • Grading coefficient G_c 16–34[b] • Shrinkage product S_p 100–365[c] • Treton impact value TIV (%) 20–65[d]	Same material as base
	Thickness (mm)	50–100	150	150

[a]Since there is no reinforcement, it would be preferable that the material would comply with the specification as wearing course material in the design manual.

[b]'Well-graded' specified in terms of G_c = (Percent passing 26.5 mm—percent passing 2.0 mm) × percent passing 4.75 mm/100.

[c]Appropriate plasticity specified in terms of S_p = Linear shrinkage [7] × percent passing 0.425 mm sieve.

[d]Appropriate coarse particle hardness specified in terms of TIV, TIV <20 means the material is too hard to be broken with a grid roller, while TIV >65 is too soft to resist excessive crushing under traffic.

[e]Specified in terms of grading curve envelop as shown in **Figure 8**.

Table 1. Minor gravel road design for a subgrade where the soaked CBR value is <3 in a wet climate.

For Do-nou applications, the percentage of angularly shaped particles that can be retained on a 37.5 mm sieve should be minimized, to avoid tearing or puncturing the bags during compaction.

The authors applied the Do-nou technology to an actual construction project, working with the local community and monitoring the conditions after the work was completed. Minor gravel road design for a subgrade where the soaked CBR value is <3 in a wet climate is shown in **Table 1**. For comparison, the conventional designs based on the design manuals used in Ethiopia [7] and Kenya [8] are also presented. Uniform sand and sandy gravel with the grading curves shown in **Figure 8** were used in the Do-nou base, even though they fell outside the specified grading curve envelope. Further research is ongoing to extend the method to use of silty clay.

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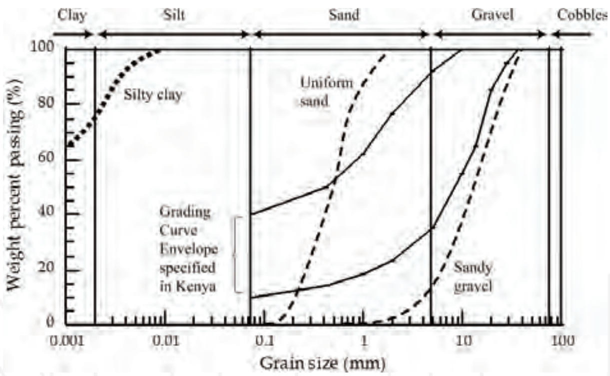

Figure 8. Grain size distribution curves of the specified gravel and others.

3.2.1.6. Practical construction procedures for communities

These procedures were designed to be practical for use in community road initiatives. Efforts are needed to control the moisture content of available granular material and to optimize the wearing course for compaction. Assessment on optimum moisture can be performed visually by observing a sample of the material that is tightly squeezing in the hand. However, access to the water needed to wet the material is sometimes challenging in the field.

The bags are filled with the granular material using a measurement container of 0.016 m^3. The open end of each bag above the fist is then tied with nylon string. These procedures (**Figure 9**) ensure that all of the Do-nou has the same size and weight, making it easy to lay them uniformly with minimum space between the adjacent Do-nou.

Figure 9. Procedures for filling the Do-nou bags with granular material: (a) Measurement container; (b) transferring material to bag; (c) open end of the bags above the fist; (d) tying with nylon string; (e) Do-nou filled with granular material.

Each Do-nou is then compacted with 15 strokes of a hand rammer. When well compacted, the dimensions of the Do-nou should be 40 cm × 40 cm × 10 cm. Any remaining space between the compacted Do-nou is then filled with available gravel material, and the next layer is laid on top.

The wearing course material is spread with a near-optimum moisture content and is first compacted manually with a hand rammer, then by passing the traffic-like gravel transportation trucks on the road. Since no specialized compaction equipment is available, the compacted lift thickness cannot be greater than 50 mm.

3.2.2. Retaining wall built with unskilled labour

Rural road projects often require the constructions of structures such as culverts, bridges and retaining walls [5]. This construction is normally performed using a mix of skilled and unskilled labour and some equipment. When choosing the most appropriate technology for this type of work, it is important to select materials that are locally available and to reduce the amount of materials that need to be transported over long distances.

Retaining walls are normally built using boulders, sand and cement by the worker groups supervised by stonemasons. This process requires the timely delivery of the various materials in appropriate quantities and masonry skills (**Figure 10a**, **b**), putting the construction of retaining walls beyond the resources available to many local communities.

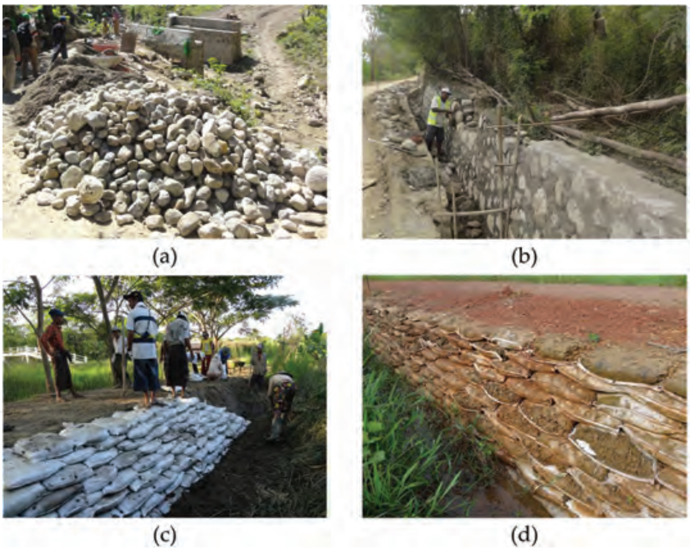

Figure 10. Construction of retaining wall: (a) Material for retaining wall with masonry; (b) construction of retaining wall by masonry; (c) construction of retaining wall with Do-nou; (d) torn bags and cemented material inside bags.

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Do-nou technology, in contrast, increases the range of work that can be undertaken by communities themselves, using only unskilled labour.

When there is no source of stones or boulders within a reasonable distance of the construction site, Do-nou filled with *in-situ* soil can be utilized as an alternative.

Unlike boulders, all Do-nou are rectangular, with uniform dimensions and weights, which make them simple to lie uniformly and to interlock. (**Figure 10c**). Uniform dimensions of Do-nou minimize the space between adjacent Do-nou, which can then be filled with mortar.

To address the vulnerability to ultraviolet light of Do-nou bags woven from polypropylene or polyethylene, the soil in the bags is mixed with cement. Initially, the soil and cement mix is confined tightly, with tensile strength generated through manual compaction. The mixture solidifies before the Do-nou bags become prone to tearing (**Figure 10d**).

3.3. Strengths and limitations

As discussed in Sections 3.1 and 3.2, spot improvement using local resource-based approach empowers communities living near rural roads to undertake their own improvements. The use of Do-nou technology in road building and structural work supports this approach. The strengths and limitations are summarized below.

Strengths:

- Compaction of soil material for building the base course can be performed manually;
- Gravel that does not exactly comply with specifications for the road base can be utilized;
- Where boulders and stone are not available, retaining walls can be built from *in-situ* soil, using Do-nou bags and cement;
- Since masonry is not essential, unskilled workers can build road structures, such as retaining walls;
- Communities can develop skills in road improvement and apply these continuously and sustainably (**Figure 4**).

Limitations:

- Roads constructed or repaired using this approach do not always meet the prescribed standards;
- More frequent maintenance is required than when conventional approaches are used;
- Although the use of locally available material is maximized, non-local materials are still required, such as Do-nou bags with required number, soil or gravel to fill the Do-nou bags, wearing course material, cement, etc.;
- Collaboration is necessary with other stakeholders, such as government institutes, NGOs, and private companies;

- Improving the most problematic road sections is only a partial solution;
- The community must be motivated to improve the roads by themselves and must be organized to work together productively.

4. Case studies from Asia and Africa

4.1. Applications in rural road improvement projects with community initiatives in Myanmar

4.1.1. Application at flooding area

4.1.1.1. Site selection

In Kayin State of Myanmar, following the recommendations of the Department of Rural Development, village Y was selected for a rural road improvement project. Through meetings with the leader and members of the community and a field survey, a 120-m length of road prone to flooding, in which the maximum water level was more than 1 m above ground level, was identified for improvement. When flooded, the community must use small boats to gain access to schools, hospitals, and markets. Accidents have occurred, and two school-age children were killed in past floods.

4.1.1.2. Design

To raise the road surface above the maximum water level, an embankment with a Do-nou retaining wall was designed, as shown in **Figure 11**. The existing ground surface was protected with single-column Do-nou layers filled with soil mixed with cement. The embankment was supported with double-column Do-nou layers, the inner filled with *in-situ* soil and the outer with soil mixed cement. The *in-situ* soil was judged appropriate for mixing with cement for use as filling material into Do-nou bags and use as the embankment material. The column of Do-nou layers was <1.5 m in height, and the slope ratio was rise of 1 over run of 0.5. Trials of the mixing ratio of cement and *in-situ* soil identified an appropriate ratio of 1:10 by volume.

4.1.1.3. Construction

Construction was performed during the dry season, from March to April in 2014, with 49 villagers working 5–6 h/day. With these resources, the length of 120 m was completed, with an embankment and Do-nou retaining wall (**Figure 12**).

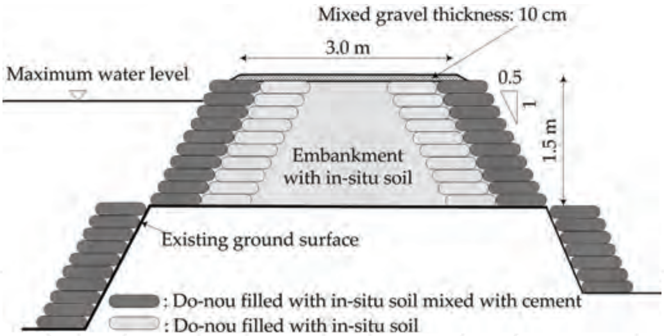

Figure 11. Design of road embankment with Do-nou retaining wall.

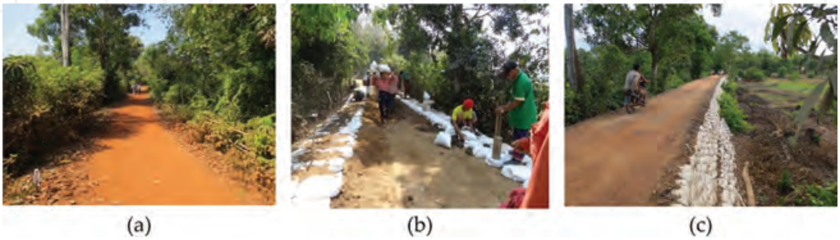

Figure 12. Construction of road embankment with Do-nou retaining wall: (a) Before construction; (b) construction of the embankment with Do-nou retaining wall; (c) after construction.

The cost of construction is summarized in **Table 2**. The largest element was the cost of cement, at 36.6% of the total, followed by the cost of Do-nou bags, and the transportation of tools and materials. The labour fee was not concern of the community members, and thus, this sum was paid into the Community Fund after construction was completed.

Item	Quantity	Unit	Cost (USD)	%	Note
Gravel	125.4	m^3	245.18	4.5	
Sand	4.6	m^3	16.40	0.3	Mixed with gravel for grading of grains
Cement (50 kg)	600	Bag	1992.60	36.6	
Do-nou bags	17,000	Bag	1717.90	31.6	
Tools	–	–	432.22	7.9	
Transportation	–	–	624.68	11.5	For tools and material
Labour fee	–	–	410.00	7.5	
Total			5438.98	100.0	

Table 2. Cost of construction.

4.1.1.4. Impact

One year later, an assessment was made of the construction site during the rainy season. This assessment confirmed that conditions remained good, as shown in **Figure 13**. The inhabitants of village Y subsequently applied the Do-nou retaining wall construction method to other sections of road, after the project ended. The work was initiated by the community leader, and the material and transportation costs were covered by the Community Fund.

Interviews with villagers revealed the following positive impacts of the project:

- During the rainy season, boats are no longer needed to move around the village;
- Students can attend schools from their home even during the rainy season, thus the absence from class is decreased;
- Patient can be transported to hospital more safely and quickly;
- Crops can be transported before spoiling;
- The community knowledge of Do-nou technology enables continuous maintenance to be conducted;
- The community has become better organized through the experience of working on the project.

Figure 13. Road condition 1 year after the completion, during rainy season.

4.1.2. Application at delta

4.1.2.1. Site selection

Ayeyarwady region of Myanmar is located at delta of the river. The sedimentary clay is prevailing. Following recommendations of a local NGO, village K in Ayeyarwady region was selected for a rural road improvement project. The people were used to construct their access roads by spreading the *in-situ* clay dug out from the adjacent rice paddy. During rainy seasons, the surface becomes muddy so that even bikes and bicycles are not passable, while during the dry season, the road surface becomes firm but rough so the traffic has to pass slowly. Due to the inaccessibility of roads, during rainy seasons, children have to be absent from their classes. In order to enable the access to the neighbouring village all the year, a 1200-m length of the existing road was targeted for improvement.

4.1.2.2. Design

Considering the current major traffic means in village K, that are bikes and bicycles, concrete pavement with 10 cm in thickness was constructed on the existing road surface as shown in **Figure 14**. In order to enable those traffic loads to go by each other, the two lanes with 60 cm in width were built. To protect the embankment from erosion caused by going up and down of the water level surrounding, Do-nou filled with *in-situ* clay were laid along the slope. Here, to address the vulnerability to ultraviolet light of Do-nou bags, Do-nou laid at 45° gradient was covered with the cohesive *in-situ* clay soil. The vegetation occurs from the attached clay and the root spreads, which stabilize the slope without confinement effect generated from the bags.

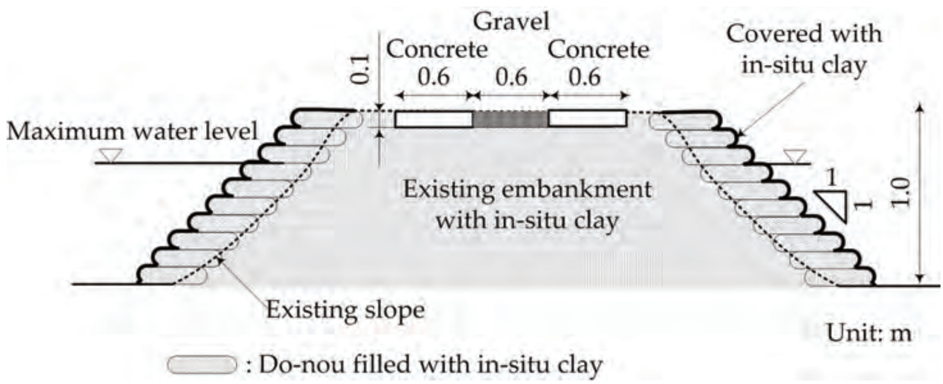

Figure 14. Design of concrete pavement and Do-nou retaining wall.

4.1.2.3. Construction

Construction was performed during the dry season, from January to May in 2014, with 20–50 villagers working 6 h/day. During the hottest season from March to May, the community managed to work at night, from 6 o'clock to midnight to avoid the heat (**Figure 15**). With these resources, the length of 1200 m was completed, with the concrete pavement and Do-nou retaining wall.

The cost of construction is summarized in **Table 3**. The unit cost per m with the cross section as shown in **Figure 14** is USD 12.32. The largest element was the cost of gravel, at 27.7% of the total, followed by the cost of cement, and tools. The labour fee was paid for the skilful workers who assisted concrete pavement work. The community members participated in the road works have no concerns on their labour fee, thus this sum was paid into the Community Fund after construction was completed.

Figure 15. Construction at village K: (a) Covering Do-nou with clay; (b) working at night; (c) bucket brigade for casting concrete.

Item	Quantity	Unit	Cost (USD)	%	Note
Gravel	212.2	m^3	4088.60	27.7	
Sand	85.0	m^3	401.80	2.7	
Cement (50 kg)	845	Bag	3440.31	23.3	
Do-nou bags	18,000	Bag	1697.40	11.5	
Tools	–	–	3309.18	22.4	
Transportation	–	–	1031.64	7.0	
Labour fee for skilful worker	60	Person day	217.79	1.5	Supervisor: 4.10 USD/day Assistant: 3.28 USD/day
Labour fee for participants			354.24	2.4	Sum amount agreed with the community, paid to the Community Funds
Others	–	–	242.26	1.7	
Total			14,783.22	100.0	

Table 3. Cost of construction.

4.1.2.4. Impact

From the assessment one year after the completion, it was confirmed that conditions remained good, as shown in **Figure 16**. The interviews with villagers revealed the following positive impacts of the project:

- The time to send children to schools is shortened and the parents spare time for other works;
- Children can attend the class even during rainy seasons;
- Bike taxi businesses are established;
- The community knowledge of Do-nou technology enables continuous maintenance to be conducted;

(a) (b)

Figure 16. Road condition: (a) Before construction; (b) condition 1 year after the completion.

On the other hand, as negative impact, the concerns on the increase in traffic accidents were raised. The training on traffic safety and installing the safety facilities, such as sign boards and bump, should be included in the project.

4.2. Construction of a vented ford in collaboration with the provincial/municipal government, community and NGOs

4.2.1. Vented ford construction site

In Nueva Vizcaya Province of the Philippines, the people of village C had suffered from flooding at the intersection of the river and the access road into the town during rainy seasons. Some sections of the road from the town to the village had been gradually paved with concrete by the provincial government, but no intervention had been made at the intersection with the river.

A Japanese NGO had trained the people of village C on the cultivation and marketing of organic agricultural products for income generation. The project had been implemented in close collaboration with local NGOs and provincial/municipal governments. However, the access problem at the intersection had constrained the project, and improvement was beyond the resources of the local governments. Surveying and construction started after the NGO consulted with the authors to seek solutions to this problem.

4.2.2. Vented ford design

Following a field survey with the municipal engineers, a vented ford with concrete slabs 4.0 m wide and 30.0 m in length was proposed, as shown in **Figure 17**.

The structure followed the basic pattern in the LBT manual [5], with Do-nou filled with soil and cement substituted for masonry. The objectives were to promote participation by all of the community members and to shorten the construction time. The ratio of cement to gravel was 20% by volume. Layers of Do-nou were combined vertically with penetrating reinforcement bars. To bear the water pressure at the upstream side, the concrete was cast to form a 20-cm-wide wall between Do-nou columns serving form.

The reinforced concrete pipes were backfilled with river gravel and with Do-nou filled with gravel. Concrete pavement was constructed in accordance with the specifications for provincial roads in the Philippines.

Due to the land use near the intersection, the axis of the vented ford could not be made vertical to the river flow, but had to be slanted as shown in **Figure 17a**.

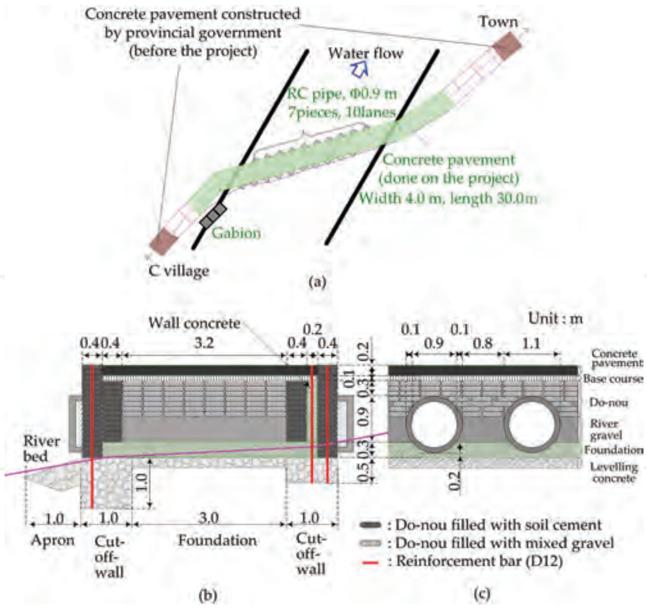

Figure 17. Plain and cross-sectional view of the vented ford: (a) Plain view; (b) longitudinal section view; (c) vertical cross-sectional view.

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4.2.3. Collaboration with provincial/municipal government, community and NGOs

Three-way discussions were held between the local government, village C, and the authors' NGO to discuss the design and clarify the role of each through the facilitations of the local and the Japanese NGO. The roles were allocated as shown in **Table 4**, and **Figures 18** and **19**.

Party	Role	Contribution
Authors' NGO	Design Supervision Procurement of materials Payment to labourers	Fund for the entire construction
Local governments	Supervision	Transportation (trucks) Equipment (backhoe, transit mixer, roller) Gravel
Community	Mobilization of labour	Cooking of lunch and refreshment, available tools

Table 4. Role and contribution of each party.

Figure 18. Work items managed using equipment provided by local government: (a) Excavation of the cut-off-wall and foundation; (b) transit mixers and water pump during casting concrete; (c) compaction of base course with roller.

Figure 19. Work items managed by the community: (a) Leveling the concrete surface; (b) filling the gaps of RC pipes; (c) laying Do-nou.

The cost details prepared by the authors' NGO are shown in **Table 5**. For 48 days between March and April 2015, 20–30 people worked for 8 h/day on the project.

Item	Quantity	Unit	Cost (USD)	%	Note
RC pipe	70	pcs	3998.40	14.1	Inner diameter 0.9 m, thickness 0.1 m
Cement (40 kg)	1620	Bag	8527.68	30.0	
Do-nou bags	9300	Bag	3124.80	11.0	
RC bars	85	pcs	462.69	1.6	D10, D12, D16, 1 pcs = 6 m
Gabion net	28	pcs	1254.40	4.4	1 m × 1 m × 2 m
Fuel	1354	Litre	947.12	3.3	For equipment and truck
Tools	–	–	839.55	3.0	
Allowances	1380	Person day	7728.00	27.2	Minimum wage per day: USD 5.6
Lunch	1380	Person day	1545.60	5.4	USD 1.12 per person day
Gravel	217.00	m^3	–	–	Provided by municipal government
Stones	82.00	m^3	–	–	For foundation, collected on site
Transportation	–	–	–	–	Two trucks with drivers, provided by municipal government
Equipment	–	–	–	–	Excavator, loader, transit mixer, roller with operator, provided by municipal government
Total			28,428.24	100.0	

Table 5. Cost of construction.

4.2.4. Maintenance by local governments and communities

In October of 2015, the area was hit by the strongest typhoon in 15 years. The vented ford overflowed, and sediment was deposited at the upstream side. After the typhoon passed, it was observed that, although the ford was partially damaged, its stability was not affected. To restore the ford's functionality, the provincial government sent an excavator for emergency removal of the sedimentation (**Figure 20**). The neighbouring community voluntarily assisted with the emergency work.

The structure was confirmed to be stable even after the flooding, and the local government and communities took ownership of the ford.

Figure 20. Vented ford affected by a typhoon and emergency work done by the provincial government: (a) Overflowing; (b) deposited sedimentation; (c) removing the sedimentation by the excavator of the provincial government for emergency.

4.2.5. Impact

The access to the local town from village C has been improved drastically (**Figure 21**). Recognizing the effectiveness of vented ford, the provincial government adopted the structure and applied the same construction method at a nearby intersection of the same river and a provincial road.

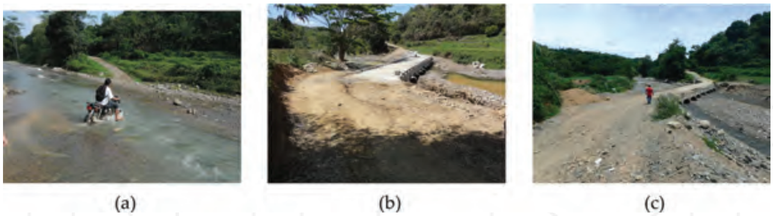

Figure 21. Conditions at the intersection with the river before and after construction: (a) Before the construction; (b) after the construction; (c) the conditions one year after the construction.

4.3. Application to rural road improvement through capacity building of farmer/youth groups in Kenya

4.3.1. Rural road improvement and impact through capacity building of farmer and youth groups using Do-nou technology

Since 2008, Do-nou technology has been used in Kenya for spot improvement using the local resource base. The approach has been transferred to 125 farmer and youth groups (**Figure 22**). Training and demonstration groups have been held, generally involving 25 members over 10–15 days. These were organized at road sections identified as problematic by the group. Do-nou technology has been used to build base courses, retaining walls at both the inlet and the outlet of culverts, and abutments of wooden bridges, as shown in **Figure 23**. In most cases, the drainage system was also improved.

Figure 22. Training/demonstration of spot improvement using Do-nou technology: (a) Training at road side; (b) demonstration on Do-nou technology.

Figure 23. Applications of Do-nou technology during training/demonstrations with farmer groups: (a) Before construction; (b) after the construction; (c) retaining wall at inlet of culvert; (d) Do-nou abutment of wooden bridge.

The training/demonstration sessions helped the trainees and neighbouring communities appreciate the benefits gained from the road works, such as better access to schools and hospitals throughout the year, reduction in public transportation fares and reduced loss of agricultural product.

However, after the training was completed, the groups were unable to continue the road projects by themselves, due to difficulties in collecting the necessary materials, in particular, granular soil for use in the bags and wearing course.

Cooperation with and supports from other stakeholders was therefore necessary to enable the community initiatives to continue. Do-nou technology and the concept of spot improvement using local resource-based approach must be understood by stakeholders such as government institutes and private road construction clients.

4.3.2. Dissemination of Do-nou technology in Kenya

Figure 24 shows the progress of the dissemination of Do-nou technology in Kenya.

Initially, to demonstrate improved access to markets of farmers, training and demonstrations were conducted with farmer groups on spot improvement using Do-nou technology. These training sessions, and the outcome of the technology, were reported to local authorities and to the Ministry of Agriculture, which was keen to promote market-oriented agriculture. However, little support or cooperation was gained to enable the road work to be continued.

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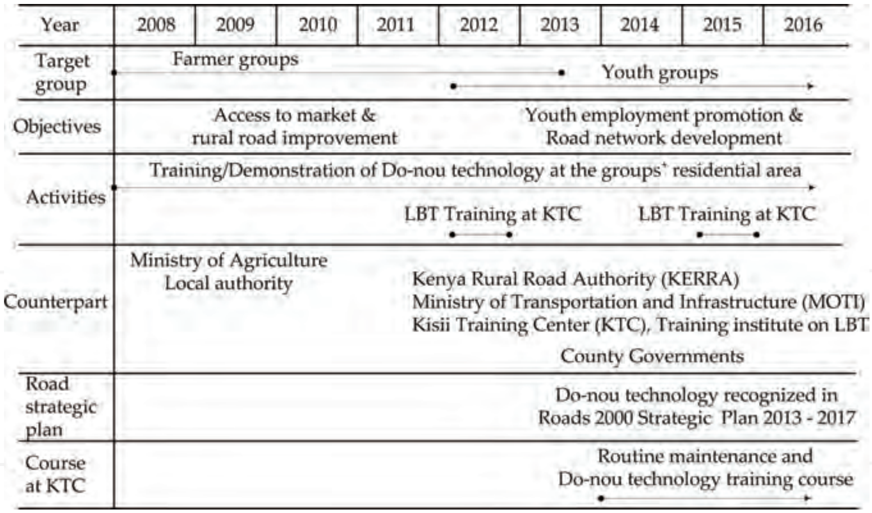

Figure 24. Progress of the dissemination of Do-nou technology.

Some of the farmer groups then established an association that undertook missions to improve rural access roads using their acquired knowledge of Do-nou technology. It was considered advantageous for the association to negotiate with stakeholders to gain their support and cooperation. However, opportunities for collaboration were limited and ad hoc, because the association was not a qualified contractor.

However, Do-nou technology was recognized by the Kenya Rural Road Authority following stakeholder meetings and field visits. The International Labour Organization funded a youth employment promotion project, in which youth groups were trained in Do-nou technology for spot improvement of their residential area. Their representatives participated in the training at the Kisii Training Center (KTC), which is the public training institute for LBT, for a six-week course on routine maintenance and business management. Ten of the 20 youth groups then established their own company, called Micro and Small Enterprises (MSEs), and began work. With the certification provided by the training course at KTC, the three companies registered as qualified contractors, allowing them to bid for government projects and thus expanding their business opportunities. Contracts for access road construction and other building works were also secured from other sectors apart from road administrators, such as health centers, schools, and churches.

In order to address the issue of youth unemployment meaningfully, the Kenyan government launched the policy, “Access to Government Procurement Opportunities”, in which 30% of all government contracts were to be earmarked for youth, women, and persons with disability, without requiring competitive bidding against established firms [10]. The policy helped the youth groups that had learned Do-nou technology and joined the training course at KTC to further expand their businesses.

Do-nou technology was also recognized in the Roads 2000 Strategic Plan 2013–2017 [11], and a training course in routine maintenance and Do-nou technology was established in the KTC program.

In 2015, the Ministry of Transportation and Infrastructure (MOTI) allocated funds amounting to about USD 229,300 to train 120 youth members in the KTC course on routine maintenance and Do-nou technology. By May of 2016, about 30% of the graduates from the course had either established their own companies or registered as qualified contractors. MOTI is now planning to adopt a specification for Do-nou technology.

4.3.3. Involving communities in road projects

Based on the experience of capacity building in Kenya, four patterns for involving the local communities in road projects have been identified. These are summarized in **Figure 25**. Pattern A is the case of a conventional road project using LBT. Patterns B and C reflect the original

Pattern	A	B	C	D
Stakeholders involved	Government/ Private client ↓ *Contract* Contractor ↓ *Empoly as labour* Community	Farmer groups (Community)	Government/ Private client ↓ *Force account/ Contract* Association ↑ *Registration* Farmer groups (Community)	Government/ Private client ↓ *Contract* Contractor ↓ *Contract* Micro & Small Enterprises (*Contract*: Government/ Private client → Micro & Small Enterprises) ↑ *Training/Certificate/ Registration* Youth groups (Community)
Technology/skill to be trained to community	Road works of LBT Instructed by contractors	Spot improvement using Do-nou technology, Group management	Spot improvement using Do-nou technology, Group management	Spot improvement using Do-nou technology, Company registration, Routine maintenance, Business management
Objectives	Road network development	Access to markets and social services	Access to markets and social services	Youth employment promotion/ Road network development
Target road	Rural roads	Rural access roads/ Unclassified roads	Rural access roads/ Unclassified roads	Rural roads
Advantage	Rural road are improved to meet to engineering and technical standard.	Problematic portions communities suffered are improved. Only simple training is required.	Problematic portions communities suffered are improved. Only simple training is required.	Youth employment is promoted. Road network is maintained.
Disadvantage	A certain amount of budget is required.	Organized/self-reliant group (community) can apply. The scope of work is very basic. Support/ cooperation is required.	Cohesive association can apply. The scope of work is basic. Business chance is limited.	Comprehensive training is required. Establishment company, registration as contractors are necessary.

Figure 25. Patterns of involvement in road works.

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purpose of developing and transferring spot improvement using a local resource-based approach, which was to provide access to communities excluded from conventional road projects executed by government institutes. Both patterns present challenges in the sustainability of road projects undertaken by communities themselves. The cohesiveness and self-reliance of the groups is key in these patterns. Support and cooperation in the provision of materials help to make the community road projects sustainable and to ensure the continuing accessibility of the rural roads.

In Pattern D, a combination of government policies on youth employment and Do-nou technology training forms the basis for helping youth launch businesses as contractors. Subsidization of the training fee (about USD 1500 per person) for a comprehensive training course on routine maintenance and business management is necessary. The commitment of those graduating from the course supports the establishment of MSEs and the registration of participants as contractor.

5. Lessons from case studies

In line with the SDGs goal of leaving no one behind, research was conducted on the provision of access to markets and social services for rural people in developing countries. Road projects executed both by government institutes and by local community initiatives were considered to be key measures for improving the conditions of rural roads. To enable work to be managed by the communities with unskilled workers, and with local resources, spot improvement using a local resource-based approach was applied. Do-nou technology was transferred to the communities and used in the improvement of problematic road sections in Asia and Africa.

In Myanmar, the road embankment and concrete pavement with retaining wall built with Do-nou were constructed. The design was intended to be the most practical for the communities and at the same time to make the portions passable all the year. For this case, not only Do-nou bags and soil, but also cement was required.

The communities were motivated with the simple but effective technology and working hard to acquire the technology and complete the road structure. The communities was well-organized and had mind-set of self-reliance so that they applied the technology to the other portion by procuring the necessary material by themselves.

The case in Myanmar demonstrates that communities that are organized and self-reliant can apply Do-nou technology sustainably, improving and maintaining their rural roads. This is a good example of the Pattern B shown in **Figure 25**.

In the case of the Philippines, funds, technical advice and mobilization of stakeholders were provided by NGOs, local governments and communities. By working together, they were able to solve the flooding problem at the intersection of a road and a river. Do-nou technology shortened the construction period and enabled all of the members to participate in the work. The NGOs played an essential role in ensuring the success of this collaborative project between government and community. Such projects can supplement government executed road projects, supporting the improvement of rural access roads.

In Kenya, government policy on youth employment promotion helped the technology gain recognition, and it was then adopted into the training courses run by KTC. Training in Do-nou technology provided the first step in converting unemployment youth into contractors. A specification for Do-nou technology is scheduled to be adopted by the Kenyan government. Adoption may increase the willingness of government or other stakeholders to provide support or to collaborate with communities that wish to improve their rural roads using Do-nou technology.

These case studies demonstrate that spot improvement and the use of locally available material approach can provide socioeconomic benefits to communities that have been isolated for years from the government and donor agency interventions in infrastructure development. Feasible designs have been developed, in accordance with the proposed approach, for the construction of base courses, retaining walls, foundations of bridges, bridges and causeways. These designs can be applied over wide areas and modified to reflect the unique conditions of each project area. The experience gained in community mobilization and stakeholder involvement, which is an essential in the proposed approach, can serve as a guide when it is applied in a new area.

In order to improve rural roads and make communities resilient to the road problem, Do-nou technology, as applied to spot improvement of rural roads using a local resource-based approach, has been transferred to 25 countries in Asia, the Pacific, Africa and Middle and South America. One of the solutions to long-neglected road problems in rural area has been developed. Research will continue to develop further appropriate technologies, accumulate and analyse cases of community mobilization, and collaboration between stakeholders and communities, and develop designs for structures under unique conditions using different types of local materials.

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Author details

Yoshinori Fukubayashi[1*] and Makoto Kimura[2]

*Address all correspondence to: yfukurin@gmail.com

1 Community Road Empowerment (INGO), Kyoto, Japan

2 Graduate School of Engineering, Kyoto University, Kyoto, Japan

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