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Review article

Appropriate Technology: Construction of Cobblestone Roads

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Abstract: Appropriate Technology with characteristic of social equity and ecological sustainability can provide a better living standard for the society by assuring the least pollution to the environment while addressing all economical classes of the society. As an appropriate technology, the construction of cobblestone roads is widely distributed in Ethiopia. It creates a job opportunity for a huge number of laborers within a short period of training time, allowing them to focus on the income-generation activities. Furthermore, it needs less cost compared to that of an asphalt road which is not eco-friendly. The aim of this communication article is to illustrate the significance of cobblestone roads as an appropriate technology, and simultaneously to suggest some possible ways for expanding this kind of technology in developing countries.

Keywords: appropriate technology; cobblestone; road construction

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1. Introduction

Ethiopia as a developing country is in a good progress in expanding manufacturing, agriculture, mining, and service providing industries, which are mainly intensive sectors of the economy. This trend is expressed by the growth and transformation of micro and small enterprises (MSE). The aim of the MSE is creating job opportunity, which is easily implementable and can involve especially the youth human resources. Most of the MSEs are characterized by labor intensive, small capital, environmentally friendly, and unnecessary imported knowledge (Ethiopian Ministry of Urban Development, Housing and Construction, 2013). Due to these characteristics, the MSEs are considered as centers of appropriate technology in Ethiopia. Among these MSEs, the cobblestone-road construction as an appropriate technology is well-known and widely spread out in Ethiopia (Trimble, 2013).

Appropriate technology could be defined as "designing modern technology so that it will be easily understandable by the common society, and it will solve the problems of the community". In fact, there is no single statement that completely defines appropriate technology. An appropriate technology may also be defined as technologies that are socially, culturally, environmentally, and economically accepted by the stakeholders (Verharen et al., 2015, Wensing et al., 2018, Rybcynzski, 1991). The common understanding of appropriate technologies is considering them as small scale, labor intensive, and usually requires small amount of money (Schumcher, 1973). After the emerging of micro- and macro-appropriate technologies (Tharakan, 2015a), the common consensus on appropriate technologies is expanded so that it can be in the form of small-scale enterprises or in the form of large-scale projects. They can also be funded by the government and/or by

non-governmental organizations as much as they use local materials and resource, build capacity and skills within a community (Tharakan, 2015b).

From the perspective of both socio-economists and politicians, the main objective of appropriate technology is benefiting and empowerment of the community (Tharakan, 2015a). Appropriate technologies can also be implemented in variety of sectors, for instance, energy, agriculture, and health (Aschalew, 2013, Tharakan, 2015a). Therefore, the construction of cobblestone roads, which is funded by the government and the community as well, is a typical example of appropriate technology in the context of a country that does not utilize its natural oil and wants to create job opportunity for huge number of jobless youths. Designing of a core curriculum for civic engagement is recommended to establish connection between the various successful appropriate technologies-based projects, and to share best practices (Wensing et al., 2018, Kim, 2014).

Unlike the last decades of the 20th century that was full of debates on what appropriate technology is, the 21st century has relatively better common consensus on it (Tharankan, 2015a, Rybcynzski, 1991). The International Network on Appropriate Technology (INAT), which is a group consisting of academicians and practitioners, is one of the stakeholders that promote appropriate technology to empower people (Trimble, 2013). INAT organizes International Conference on Appropriate Technology (called ICAT) to address various topics: agriculture, health, energy, education and policy.

The beginning of cobblestone road in Ethiopia is traced back to the year 2005 in Dire Dawa, the second largest city next to Addis Ababa (Aschalew, 2013). In 2006, Mekelle was the next one in training workers for construction the cobblestone roads with modified processes. A few months later, other cities such as Adama, Hawassa and Bahir Dar have followed this activity of road construction (Aschalew, 2013). Later in December 2007, the Ethiopians Road Fund (ERF) has given direction to other towns and cities to follow the Dire Dawa's example (Ethiopian Ministry of Urban Development, Housing and Construction, 2013). Until the year 2013, in capital city of Addis Ababa alone, about 2,240 MSEs were established and engaged in this cobblestone road construction. As a result, in 2013, the cobblestone road construction can create a job opportunity for about 489,000 unemployed citizens throughout the country, among these, 195,600 (40%) of the beneficiaries were female laborers (Ethiopian Ministry of Urban Development, Housing and Construction, 2013).

At the end of 2011, the cobblestone road construction program was stretched out to 120 towns and cities across the country. Resultantly, about 2.2 million square meters have been cobblestone-paved with employment of ca. 130,000 people (45 % of them are women) in this MSE sector. Currently, Hawassa, Bahir Dar, Mekelle, Dire Dawa, Harar, and Addis Ababa have established their own training schools for this purpose of road construction, which also provides an employment opportunity for the disabled although the employees are mainly the youth. The increasing share of female laborer in this road construction, has contributed to the gender equality in country with characteristic of social sustainability. Considering environmental-friendly position-creation using this cobblestone road, the UN-Habitat has awarded a prize to the Ministry of Urban Development, Housing and Construction (MUDHCo) of Ethiopia. The implementation of the cobblestone roads in Ethiopia has been carried out by MUDHCo in partnership with the German organizations, Deutsche Gesellschaft fűr Internatonale Zusammenarbeit (GIZ) and KfW Development Bank (Ethiopian Ministry of Urban Development, Housing and Construction, 2013). This communication is organized as follows: the overview of construction of cobblestone roads, the analysis of economic and environmental effects, and the final conclusion.

2. Overview of Construction of Cobblestone Roads

The production of the cobblestones starts from the quarry where large stones are obtained using both machinery and human labor. The stones then were transported to the chiselers working in nearby sub unit of the project area. The first step of the chiseling is cutting the giant stones to small pieces based on the type of cobblestone that the chiseler wants to produce. There are generally three types of cobblestones which are classified in terms of their size as small medium and large. Their dimensions are 10×10×10 cm^3, 15×15×15 cm^3, and 10×20×40 cm^3, respectively. While measuring these dimensions 1 cm extra is left so that the cobblestone will not be too small while making it relatively smoother as the next step. Generally, ±1 cm is tolerable for any two of three dimensions.

The small cobblestones take the majority of the production, and used for the general pavement. The middle-sized cobblestones are paved by following a straight line that crosses a sloppy road, in which case their heavier weight is used to prevent the small cobblestones from sliding. During pavement, the line of those middle-sized cobblestones may be made at about every 5 to 10 meters gap, depending on the slope of the road. The large size cobblestones are paved on both sides of the road, where their longest edge will be parallel to the road and it maintains the width of the cobblestone road.

A cobblestone road is built after a ground work preparing the bare road to be ready to hold each piece of cobblestone in a stable manner, so as to provide comfort for both vehicles and pedestrians. In each stage of construction, it needs to use locally-available indigenous resources (usually, ceramics) efficiently (Chiang et al., 1997). Once the ground is labelled, the first stage is to cover it by red ash (lava or trachyte and granite), as shown in Figs. 1(a) and 1(b). The next stage is to make a second layer of gray sand (basalt, granite), shown in Fig. 1(c), laid down to keep the cobblestone at a fixed position. The three types of rocks, basalt, granite and trachyte, are resulted from volcanic eruption, and adequately available in Ethiopia (Hagos & Koller, 2010, Sembroni et al., 2016, Walle et al., 2000). Note that Ethiopia is one of the countries through which the Great Rift Valley crosses, making the land rich in gray sand (Aschalew, 2013). The final stage is paving the cobblestone with considering a decorative alignment, Figs. 1(d) and 1(e). In fact, this alignment also has structural application to prevent sliding of the stones. As shown in Fig. 1(f), a load pressure is applied to give strength, stability, and maximum leveling on the road, which process makes the final layer compact together with those made beneath it. Note that all resources aforementioned are locally available (Walle et al., 2000). This local availability is a characteristic of appropriate technology, encouraging nearby natural resources, which, of course, contributes much to reducing the dependence of road construction on the asphalt materials with some foreign petrochemicals.

Figure 1. Construction of cobblestone road in Adama, Ethiopia: (a) the leveling of a road, (b) red lavas, (c) crushed sands, (d) cobble stones, (e) fill the gap with crushed sands, and (f) complete leveling of road using a roller.

The quarries are available enough around Addis Ababa. Since stone is heavy (its weight is around between 2.2 and 2.6 tones/m^3), the availability of a quarry within a maximum distance of 20-30 km makes it easy to transport and provide the materials at a reasonable price, which guarantees the construction of cobblestone roads very competitive (Ministry of Urban Development and Construction, 2012, Negash, 2011). For example, in Addis Ababa, there are different quarry sites, which includes Tafo located in Yeka District (southern outskirts of the city), around Gelan and Hanamarim Area in Akaki Kality District. The quarry is also site for the production of the raw materials, cobblestones. Every piece of cobblestone is produced by chiselers with sufficient skill for producing more cobblestones per a laboring time. It has been known that about 70% of the job opportunity in Ethiopia is created at this site through this cobblestone construction (Merhatsidk, 2014). In the years 2013 and 2014, there were 7,344 enterprises with over 70,000 labor powers in Addis Ababa, working at the quarries for both cutting cobblestones and laying the stones. The 63,000 people, 90% of them, are working at the quarries for cutting the stones. Hence, it seems to be important to analyze more details about this cobblestone road from both the economic and the environmental points of view (Merhatsidk, 2014).

In spite of all the above advantages (mentioned in section 1) of cobblestone road construction, it has some drawbacks. Typical of them are:

- The skill of making cobblestone or the pavement is not usually applied to do any other kind of work.
- The working environment is dusty and dangerous where one may hurt himself or his/her colleague by sparking of gravels while chiseling, or by sparking of wedge while cutting a big stone as obtained from quarry into pieces.
- The skills developed both at quarrying and chiseling, are not usually shown to be grown and help one in his carrier development.

3. Analysis of Economic Effect

Construction of general asphalt roads is about twice expensive than that of cobblestone ones. In addition, the maintenance of the latter is easier than that of the former. Cobblestone roads are easily replicable with a short-training time, within two to three weeks. These merits enhance the development of cobblestone roads with economic feasibility. It is also a solution for the challenge posed by the cost of the asphalt-road construction. In spite of the fact that most cobblestone chiseling sites are not safe enough for the laborers, the cobblestone-related work is offering work opportunities for thousands of people from chiseling (Figs. 2a and b) up to paving (Fig. 2c). It is serving as one way of efficiently utilizing the youth labor in Ethiopia (Wensing et al., 2018). Until the year 2013, the 489,000 unemployed citizens could have income sources from this cobblestone affair. For example, Addis Ababa alone offered a job opportunity to 70,000 unemployed persons. In addition, this construction is totally independent on imported goods instead it utilizes indigenous knowledge systems (Tharakan, 2015a, Thrakan, 2015b), indicating the saving of hard currency (United States dollar, USD), i.e., a contribution to domestic economic activities.

Figure 2. Cobblestone works: (a) chiseling site 1, (b) chiseling site 2, and (c) road paving.

The individual chiselers obtain payment per the number and type of cobblestones they produce every two weeks. In fact, the amount of stone provided for them also will be considered during the payment, to measure their efficiency and prevent wastage of stone during cutting and lack of maintaining the right dimension. On the other hand, the chiselers are usually kept busy, since the payment depends on their productivity. This system does not allow them to lose time resulting in the waste of their money. Thus they may focus on their own works to make more money although this work condition makes them desire another work which is less labor intensive and more profitable. In average, a chiseler earns about 4 USD per day, resulting in above the poverty threshold for cobblestone-laborers.

4. Analysis of Environmental Effect

Even though cobblestone road is not applicable for high-speed roads, for instance highways, where asphalt road is necessarily required, there are several positive impacts of a cobblestone road to the environment. The prevention of flooding, reduction of light reflection from asphalt roads, minimization of unnecessary utilization of the non-renewable asphalt materials are some of them. Note that the asphalt road does not allow rain water to sink into the ground. Importantly, due to the environmental-friendliness, and easy construction, the cobblestone roads cover 73 km of the road in Dire Dawa, compared to 47 km made with asphalt roads in 2013. Investments in "cobblestone" roads have attracted a great international attention, when UN-Habitat awarded a prize to the Ethiopia MUDHCo in 2013 (Ethiopian Ministry of Urban Development, Housing and Construction, 2013). However, note that, in fact, in the European countries, the cobblestone road is used as an alarm to prevent traffic accidents for the pedestrian through the frictional sound created by the car tires (see Figure 3). Furthermore, the cobble stones may be useful for artistic beauty, vibration dissipation (or shock adsorption) and the aforementioned rain drainage. Specifically, because many peoples are using mobile smart phones, the pedestrians need much more attention and protection from any kind of vehicles. From this sense, the cobblestones should be helpful in various ways for citizens in the modern society as well in this 21st century and beyond.

Figure 3. Cobblestone roads in Linköping, Sweden, Northern Europe. (a) Crosswalk and pedestrian roads are made by cobble stones. (b) Pedestrian road between buildings are made by cobble stones.

5. Conclusions

The construction of cobblestone roads is widely used as an appropriate technology in Ethiopia. Such kind of technology is believed to be very important especially for the developing countries, which should provide the work opportunities for huge number of unemployed people. Hence, considering this significance of human-centered technologies, the public universities in Ethiopia emphasize the appropriate 'prototype' R&D for eventual mass production via technology transfer. However, it seems to be very challenging to successfully securing this useful technology for our community's true wellbeing and better life. Hence, it should be imperative to strengthen the science and technology sectors in the higher education with a balanced view in the appropriate and state-of-the-art high technologies, covering the current and future needs of nation.

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References

Aschalew, M. (2013). Cobblestone's Rocky Road. Forture, Addis Ababa, Ethiopia.

Chiang, Y.-M., Birnie III, D., and Kingery, W.D. (1997). Physical Ceramics: Principles for Ceramic Science and Engineering. John Wiley & Sons, Inc., New York, NY.

Ethiopian Ministry of Urban Development, Housing and Construction, MUDCo. (2013). UN-Habitat awarded the Ethiopian Ministry of Urban Development, Housing and Construction, MUDCo.

Hagos, M. and Koller, F. (2010). Geochemical characteristics of the alkaline basalt and the phonolite–trachyte plugs of the Axum area, northern Ethiopia. Austrian J. Earth Sci., 103 (2), 153–170.

Kim, J.Y. (2014). Materials science, technology, and innovation in sub-Saharan Africa. Afr. J. Sci. Technol. Innov. Dev., 6 (4), 367-368.

Merhatsidk, M. (2014). Colossal Cobblestone Costs a Headache for Roads Authority. Fortune, Addis Ababa, Ethiopia.

Ministry of Urban Development and Construction, MUDC. (2012). Urban local government development project. Addis Ababa, Ethiopia.

Negash, A. (2011). Contribution of Cobble Stone Enterprises to Urban Household Food Security: The Case of Gulele Sub-city. Addis Ababa University, Addis Ababa, Ethiopia.

Rybcynzski, W. (1991), Paper heroes; appropriate technology: panacea or pipedream. New York: Penguin.

Schumcher, E.F. (1973). Small is Beautiful: Economics as if People Mattered. New York: Harper Perennial.

Sembroni, A., Faccenna, C., Becker, T.W., Molin, P. & Abebe, B. (2016). Long-term, deep-mantle support of the Ethiopia-Yemen Plateau. Tectonics, 35 (2):469-488.

Tharakan, J. (2015a). Integrating indigenous knowledge into appropriate technology development and implementation. Afr. J. Sci. Technol. Innov. Dev., 7 (5), 364-370.

Tharakan, J. (2015b). Indigenous knowledge systems – a rich appropriate technology resource. Afr. J. Sci. Technol. Innov. Dev., 7 (1), 52-57.

Trimble, J. (2013). The Historical Development of the International Network on Appropriate Technology (INAT). Afr. J. Sci. Technol. Innov. Dev., 5 (4), 339-341.

Verharen, C., Bugarin, F., Schwartzman, D., Tharakan, J. , Gutema, B., Fortunak, J. & Middendorf, G. (2015). Ethics and extinction: Micro versus macro appropriate technology. Afr. J. Sci. Technol. Innov. Dev., 7 (5), 381-385.

Walle, H., Zewde, S. & Heldal, T. (2000). Building stone of central and southern Ethiopia: deposits and resource potential. NGU Bull., 436, 175-182.

Wensing, A. J., Wensing, E. J. & Virgo, M. (2018). Towards a core curriculum for civic engagement on appropriate technology: Characterizing, optimizing and mobilizing youth community service learning. Afr. J. Sci. Technol. Innov. Dev., 10 (7), 867-877.