Introduction of sustainable low-cost housing. Experiences from a demonstration project viewed from an innovation diffusion perspective

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Abstract

The purpose of the study is to describe and analyse, from an innovation diffusion perspective, factors important when using demonstration projects as a tool for introduction of sustainable low cost housing. The study is focused on Ethiopia, a country with big challenges as regards population increase, lack of resources, deforestation, land erosion and a general need for better and sustainable housing, especially in rural areas. The study is furthermore focused on the adobe technology as a more sustainable alternative to the traditional building technology which is very timber consuming. Many attempts have been made to introduce this technology with the use of demonstration buildings. A great part of these attempts have failed, some have been successful. In order to study and discuss important factors in connection with the use of demonstration buildings, a project executed some years ago in southern Ethiopia has been analysed. The study is based on findings collected during and after the erection of these buildings mainly through practical tests, interviews and observations. From a technical point of view this demonstration project was successful. It was possible to develop an appropriate production technology and the result was buildings with a good standard and good function. Experiences up to now indicate a good durability. From an innovation diffusion perspective however the demonstration buildings have not fulfilled their purpose. The impact in the region seems to be very small. The conclusion in the paper is that the reasons behind this failure mainly are: (1) Lack of clear and visible relative advantage in comparison to the traditional building technology. The supply of construction timber in the area in question is still good. (2) Lack of a champion advocating the technology by using the demonstration buildings and thereby giving the message to the society that the technology is valuable and trustworthy. (3) Lack of continuity in the demonstration efforts, as a result of the lack of a champion.

Keywords: innovation diffusion, adobe, demonstration project, sustainability, low-cost

1. Introduction

Ethiopia is currently ranked as number 174 of 187 countries in the world by the Human Development Report (2015). The ranking is based on a Human Development Index which is a composite index measuring among other things the standard of living. The low ranking indicates difficult living conditions for the vast majority of the inhabitants of Ethiopia. This is caused by current serious problems such as a very large population with a high population growth rate putting a high pressure on already inadequate resources causing e.g. high rate of deforestation, (Barton and Dlouhá, 2014).The deforestation in its turn causes other problems and difficulties, e.g. land erosion and lack of suitable timber for construction, (Barton and Dlouhá, 2014).

In 2011 the Ethiopian Government issued the document "*Ethiopia's Climate-Resilient - Green Economy. Green economy strategy*" (2011). In this publication it is stated that Ethiopia aims to achieve middle-income status by 2025. The aim is to develop a climate-resilient green economy by avoiding sharp increases in greenhouse gases (GHG emissions) and unsustainable use of natural resources.

A vast majority of the Ethiopians, about 80%, are living in rural areas. This means that a majority of the Ethiopians have rather bad housing conditions. A study by Kumie and Berhane (2002) indicated poor living conditions for many persons living in rural areas, with overcrowded houses with poor sanitation conditions. The authors stress that this fact predisposes to adverse health conditions and that appropriate interventions are needed.

As regards the Ethiopians living in urban areas the average situation seems to be better with a much bigger variation in living standard from case to case; (Abelti et al, 2001) and (Bihon, 2007). Anyhow, the need of improvement is great also for urban areas.

From what is written above it is obvious that there is a great need to improve the housing conditions for many Ethiopians. New methods for erecting dwelling houses must be introduced. These methods must be sustainable and take into account the present situation in the country and the Ethiopian Governments aims regarding GHG emissions and the sustainable use of natural resources. In addition to this, the methods must result in durable and safe dwelling houses that have a healthy indoor climate. A technology that is interesting in this context for erection of walls is the adobe-technology.

During the years several attempts have been made to introduce this technology in Ethiopia. Many times demonstration buildings have been erected in connection with the introduction. Some of the attempts have been and are successful, many have been failures.

The aim of this paper is to present and discuss from the innovation diffusion perspective factors of importance for the introduction of adobe-technology technology in Ethiopia. The discussion is based on findings and experiences from a demonstration project executed during the years 2009 – 2012. The aim of the demonstration project was to introduce this technology in a region in southern Ethiopia. The data from this demonstration project presented in this paper was collected mainly thorough practical tests, interviews and observations.

2. Innovation diffusion

Innovation has been defined in many ways, in different contexts, but all are more or less pointing in the same direction, with slight differences. One definition that has gained a wide acceptance is “the implementation/adoption of new or significantly improved production or delivery methods” (OECD, 1997). It is useful as it links innovation to value creation and recognize this in a broader sense than short-term economic perspectives, as well as move away from the linear process best measured by R&D spending (Loosemore, 2014). That makes it also useful in this context. Innovations evolve in an economic, social, cultural and political context and are highly influenced by this (Weisenfeld, 2003). This explains why innovation vary between different contexts such as industry, political, national etc. This suggests that different national contexts when transferring an approach or technology between contexts, for example when transferring between countries, need to be addressed (Abdul-Azis, 2002). Developed and developing countries have to address different problems in relation to innovation (Bröchner, 2011). Differences in education, communication, business maturity etc all affect innovation. As learning is a central to innovation, and it is a social activity, which involves interaction between people (Lundvall, 1992) it is important to have a supporting framework around the innovation project or innovation diffusion project suited to the context enabling people to learn about the innovation.

Undertaking construction innovation outside of projects appears to be a very unusual process (Tatum, 1987). This result in that innovation in construction, from a process perspective, is complex and involves different stakeholders and components (Manseau, 2005). From a technical perspective the innovation in the current context is not as complex as in most western countries, but the process may be as complex, but in other ways. The development of a collective understanding of the innovation and building trust at the operational level where individuals are more likely to encounter it is important. A critical success factor is involvement, from the early stages of development, of those who will be responsible for implementation, possibly requiring mediation between new development and existing routines and duties within the organizations affected (Barlow et al., 2006).

In an earlier study where common areas of importance for the diffusion process, compare with Stoneman (2001), have been applied on non-commercial innovation diffusion in developing countries, it was found that the factors, apart for commercial factors, are applicable (Hjort and Widén, 2015). Those cases where there was a champion, where there was a “market”, a need, where the cultural context allowed for the innovation, the diffusion succeeded. In the cases where a majority of the factors were missing the diffusion failed. Other factors that may be of importance for diffusion, not specifically studied in the earlier work, are relative advantage, compatibility, complexity, trialability and observability (Rogers, 2003). Relative advantage is how much better the innovation is perceived to be than the technology it is supposed to replace. Compatibility is the extent an innovation fit within the existing values, past experience and needs of the adopters. Complexity addresses how difficult the adopter finds the technology to use. Trialability deals with the adopters’ potential to experiment with the technology. Observability is about how the results are visible to others. Some of these factors are to some extent overlapping the factors tried earlier, for example relative advantage share much with if there is a market. The market will be there if there is a relative advantage of the innovation. Compatibility has some parts in common with the cultural dimension. Does the innovation fit into the contextual setting where it is to be diffused? Whereas complexity, trialability and observability are not dealt with to the same extent explicitly in the earlier study, compare with Hjort and Widén (2015).

3. Alternative building technologies

The traditional way of erecting a dwelling-house in Ethiopia is to use a framework of timber in the walls. Timber-poles with an appropriate length are put into the soil. The timber-specie mainly used varies from region to region according to availability. In the highlands the timber-specie mainly used, has been and still is fast growing Eucalyptus. However, in order to enhance the durability of the walls, some poles of more durable timber species, have been used in the walls with a spacing of approximately 1000 mm. The framework is provided with a roof structure which is covered with grass or corrugated iron sheets. This framework is later on covered with mud mixed with straw. Sometimes one of the last steps in the process is to provide the walls with a “foundation”. This is done by arranging a stone masonry around the outer walls. It is clear that this masonry actually is not a real foundation but protection of the lowest part of the walls. The timber core of the walls are in contact with the soil and can thereby be exposed to termite attack and decay caused by high moisture content. With regard to this the use of more durable timber in the walls is crucial.

Dwelling houses that give a good indoor climate and that are reasonably durable can be erected if these houses are provided with a proper foundation and sufficiently long roof overhangs. Despite this it is very doubtful if this technology can be used on a broader scale in the future. There are important reasons for this standpoint. Firstly, the traditional technology is very “timber-consuming”. With regard to the current de-forestation in Ethiopia and resulting timber-shortage, it seems clear that an alternative technology must be used. Secondly, the possibility to obtain durable timber species, traditionally used in connection with construction of walls, e.g. Thid (*Juniperus Procera Hochst*) and Kosso (*Hagenia Abyssinica*), will be very limited in the future, (Bekele et al, 1997). Because of the ongoing deforestation such species are very difficult to obtain, at least to a reasonable price. This has had, and will have, a serious impact on the possibility for ordinary people to erect dwelling houses with framework that could resist termite-attack and decay.

The termite problem, which is underlined in Berhane (1984), seems to have be a growing problem in Ethiopia a rather long time. A rather recent study on termite damage on rural housing in the Central Rift Valley in Ethiopia, (Debelo and Degaga, 2014), confirms this. According to this source the wood/straw thatch buildings characteristics of farming communities in Ethiopia, are susceptible to termite damage, particularly in the tropical savanna areas. They forward a source, (Abduraman ,1990) which reports that in western Ethiopia, where the termite problem is accentuated, thatched roof huts are destroyed in less than five years and corrugated iron roof houses in less than eight years.

A realistic alternative to this traditional building technology is to use adobe blocks for the walls, i.e. to build walls in dwelling houses with sun-dried blocks made of mud; with or without straw included. The technology is not a traditional technology in Ethiopia as a whole, although there are some areas where the technology has been in use for a rather long time, e.g. in the eastern Ethiopia.

In a recent study, (Petersson and Ström, 2015) the spread and diffusion of this technology in some locations in the eastern, the central, south-central and western parts of Ethiopia has been analyzed. As regards the diffusion, adoption and spread of the adobe technology the main of the study result can be presented as follows:

- In some parts of the country, mainly rural, there is a development which can be described as a spontaneous spread of the technology. The technology is commonly adopted and the driving force behind this development is clearly the present effect of deforestation – lack of construction timber at reasonable prices. This is the case in some parts in Eastern Ethiopia and in the Central Rift Valley.

- During the years a number of initiatives have been taken in order to introduce the adobe technology in Ethiopia, both in rural areas and in urban centers. The erection of demonstration buildings has been an important part of these initiatives. Most of these initiatives seem however to have failed, as they have not resulted in a sustainable diffusion of the technology. The reasons behind this are many and interdependent. Petersson and Ström (2015) mention, among other things the following: lack of continuous efforts, neglecting of training and education, market forces, negative attitudes from authorities and absence of advantages that are easily and clearly identified.

- In some cases the adobe technology has been used in a way that is not recommendable from a technical point of view. The reason behind this seems to be a lack of understanding of the limitations of adobe and a lack of experience. It can be anticipated that cases like these creates negative demonstration that limits further diffusion of the technology instead of promoting it. These observations underline the importance of proper demonstration and education.

Several cases in Ethiopia, see e.g. Hjort and Sendabo (2007), show that durable houses with a good indoor climate can be built by a proper use of adobe technology. The technology has many advantages: it is real low-cost, local material can be used to a very great extent and the “timber content“ is very low. In addition to this it is rather simple with no need of special equipment with the exception of some simple forms for block-making. The technology has really the potential to become “the property of everybody”.

As regards durability however a special concern must be given in some regions to termite-attack also for adobe-houses. This is clearly demonstrated by Debelo and Degaga (2014). In connection with site-visits in Central Rift Valley in Ethiopia they have noted that more than 85 % of 35 houses built by mud blocks where prone to termite infestation. The corresponding figures for 23 houses built according to the traditional technology was 100%. It can be noted that the great majority of the houses, both adobe and traditional, were rather young, i.e. less than six years old.

Debelo and Degaga (2014) argue that it is more likely that infested wooden wall houses have a shorter life then adobe houses as they attack the load bearing structure, the wooden wall. However, also in adobe houses, the termite can cause serious problems. In adobe walls they can simply move through the walls without affecting these and the roof structure and cause heavy damages.

4. The demonstration project

At Halmstad University studies concerning low-cost housing with a special focus on the Kambaata Region in South Central Ethiopia have been conducted for several years; (Hjort and Sendabo, 2004). The overall aim has been to introduce low cost housing technologies and at the same time study and analyse the attitudes of ordinary people towards these technologies. From the beginning the importance and necessity of erecting demonstration buildings have been underlined.

In accordance with this a project aiming at erection of four demonstration buildings in the town of Durame in the Kambata Region was initiated. The aim was to study and demonstrate two low-cost housing technologies; adobe technology and a technology based on cement stabilised soil blocks. The purpose was to get a basis for technical studies as well as studies concerning attitudes. The technology based on cement stabilised soil blocks will not be commented further in this paper.

When the project started the adobe technology was by and large unknown in the Kambaata Region. Although this region was and still is densely populated, the access to timber for construction purpose was and still is rather good, at least as concerns eucalyptus. This means that an important driving force for a spontaneous development of the adobe technology was and still is lacking.

The project was planned and conducted in cooperation with a local development organisation. The plan was that this organisation should own and use the erected demonstration buildings in the future. The work at the site started in the beginning of 2009. Due to different difficulties the project was delayed and the demonstration buildings were not finalized until the beginning of 2012.

The studies related to these demonstration buildings can be divided into two groups: studies which focuses on technical issues and studies related to attitudes towards the new technologies. They have been executed before, during and after the erection of the demonstration buildings, see Table 1.

Table 1. Studies within the project – overview.

Type of study	*Before erection*	*During erection*	*After completion*
Technical studies	*Trial tests of soil reported in Andersson and Berglund (2002)* *Laboratory and field tests regarding adobe blocks; reported in Hjort (2009).*	*General observations with focus on methods for weather protection during manufacturing of blocks and masonry work of walls.*	*Follow-up studies that will focus on durability and function.*
Studies regarding attitudes		*Observations* *Inquiry form*	*Observations* *Interviews.*

The detailed design of the demonstration buildings was executed by two BS.C students. It is described in Johansson and Wartainen (2008). These two students based their design from findings obtained during a field study in Ethiopia. An essential part of their field study was a visit to Challia in Western Ethiopia, where they studied a successful low cost housing project. Interviews with people living in houses erected by adobe technology were an essential part of their study.

Three buildings were designed according to the following:

- Buildings: Dwelling House, Kitchen and Toilet:
- Sizes: Dwelling House : 5,5 x 5,8 m^2, Kitchen: 3,4 x 3,4 m^2, Toilet: 2,5 x 2,5 m^2
- Foundation: Stone masonry for all buildings
- Walls: Adobe;
- Roofing: Trusses of eucalyptus. Corrugated iron sheets for all buildings
- Flooring: Concrete slab on natural stone for all buildings
- Ceiling: Dwelling House Of cloth
- Doors and Windows: Wooden. Locally fabricated for all buildings

This is a description of the main features of the design. However, many important details are discussed and appropriate solutions are proposed by Johansson and Wartainen (2008). The following can be mentioned: foundation details, roof overhang, securing of roofing against wind-forces, fastening of door and windows.

The soil available at the spot was used for the production at the site of adobe blocks with the size 150 mm x 200 mm x 400 mm. The soil, taken at a depth of about 500 mm after the topsoil had been removed was mixed with water and straw. The straw, consisting of” teff-straw” was purchased locally. Simple forms made of ply-wood were used. These forms were open in the bottom and in the top. The manufactured blocks were stored and cured, at a first stage inside a store and at a second stage under a weather protection roof, see below. The expected and intended curing time was 28 days. However, for some of the manufactured blocks this time was prolonged considerably due to rainy and thereby humid air conditions. As mortar in the adobe walls soil mixed with water and straw was used.

The weather in Durame and its surroundings seems to have become unpredictable. Because of this the erection of a temporary roof structure was necessary as adobe blocks are very sensitive against water and wetting up. Because of this, and because of difficulties in planning the project work in relation to rainy periods, a temporary roof structure acting as weather protection was erected for the Dwelling House. This temporary roof structure consisted of the final roof structure (eucalyptus trusses, eucalyptus purlins and corrugated iron-sheets) for the building in question resting on temporary eucalyptus poles. The manufactured blocks were in a first stage stored below this temporary structure. In a second stage the walls were erected below it. At a final stage the roof structure was made to rest upon the walls and the eucalyptus poles were removed.

The general impression and experience from the use of this technology in Durame is that it is very suitable for the region and that it is easily understood and easily adopted by workers involved. The manufacture of adobe blocks and the erection of the buildings arouse a great interest among the inhabitants of Durame and most people expressed a positive attitude towards the technology.

In Table 2 the result from a questionnaire regarding the attitude towards the adobe technology is presented. The questionnaire was written in the official national language amharinja and in the local language kambatinja. It was made with the erection of the demonstration buildings as a reference. The questionnaire was distributed to 40 persons whose answers were analysed.

Table 2. Studies of attitudes towards adobe technology

Part	***Statement***	***(%) responding positively***
Regarding the acceptance of adobe technology	*I don´t support the idea*	*5*
	I support the idea	*93*
	I support the idea but I don´t think it will be accepted	*2*
Regarding training in adobe technology	*I am willing to participate*	*90*
	I am not willing to participate	*5*
	Before I answer – let me see the training	*2*
	No answer	*2*

5. Follow-up studies

During a visit in the beginning of 2015 to Durame observations and semi-structured interviews in the region were made. The observations showed that from a technical point of view the demonstration buildings were in good condition. Some defects were however noted, e.g. has the cement-lime plaster on the walls, which is intended to protect the walls from rain, come loose. It was also noted that the demonstration buildings were not used; neither by the local development organisation in its daily business, nor as demonstration objects related to ongoing education regarding adobe technology.

At an interview with a person representing the local development organisation it was mentioned that this organisation, due to lack of resources, had not been able to utilise the demonstration buildings as intended from the beginning. One of the intentions had been to continue with educational activities within adobe technology with the use of the demonstration buildings as reference objects.

The observations indicated further that the impact of the project and the demonstration buildings with regard to introducing the adobe technology in Durame and its surroundings was very small, if any. This impression was confirmed by interviews. At the interview with the person representing the local development organisation it was stressed that the adobe technology would have big advantages as a building material in the Durame region but that it has not been adopted by the local population mainly due to lack of knowledge.

6. Concluding discussion

The project showed that it is possible to erect durable and functional adobe buildings in the Durame area. Appropriate material is available and the technology can easily be understood and adopted by local workers. Furthermore, it showed that it is possible to handle the somewhat unpredictable weather conditions in the area by erection of a temporary roof structure that later on can be transferred into the permanent one.

The outcome of the project with regard to introducing a new technology can be discussed and analysed from an innovation diffusion perspective based on the attributes defined by (Rogers, 2003):

"***Relative advantage"*.** The relative advantage of the adobe technology, in relation to the traditional technology, might be underestimated or even denied by ordinary people in Durame. In this region there is no shortage of timber for construction; one of the main driving forces behind the spontaneous spread of the technology in other regions in Ethiopia. Other advantages, such as a better indoor climate and a better resistance against termite attack can only be perceived by the use of the building and after a longer period respectively.

*"**Compatibility" .***The adobe technology can be regarded as a compatible technology as mud mixed with straw is a very important part of the traditional building technology. In accordance with this working with mud has a long tradition in Ethiopia. However, working with clay has low status in Ethiopia; (Hjort and Sendabo, 2005). This might deter potential users from building their dwelling house almost entirely of mud.

*"**Complexity".*** Adobe is a simple technology; it is easy to understand and it is easy to adopt as clearly demonstrated during the erection of the buildings. However, the use of a temporary roof structure as a shelter and as a storage area and later on using this as permanent roof structure might have been regarded as complicated and difficult. It is possible that this part of the process has deterred potential users from adopting the technology.

"***Trialability".*** The adobe technology offers a good trialability as such. It is thus possible for a potential adopter to try the technology in small scale, for instance by using it for a minor building, e.g. for a store or similar. In this case this has only been done when executing the demonstration project. The reason for that is that the organisation championing the diffusion had to withdraw earlier than planned.

*"**Observability"*** The adobe technology offers a good observability of its buildability which was used in connection with the demonstration buildings erected in Durame. But, the observability of the finished product, its durability, indoor climate etc has to be observed for some time, years. As the building has not been used and the organisation championing the diffusion withdrew this has not been done in this case.

From a comparison between this study and the study presented in Hjort and Widén (2015) it is clear that the role of a champion is very important as is the perceived relative advantage and the cultural context. In this case several of the factors pointed out by Rogers (2003) was not fulfilled, but could, or would, have been if a champion had been present over time, also after the demonstration project finished.

This study, together with the earlier study, forms an interesting base for future studies of non-commercial innovation diffusion in developing countries. In future studies the focus will be on the role of the champion of the innovation over time, the role of relative advantage and the cultural context and how these influence the success of diffusion, as well as how these influence the other factors said to be important for innovation diffusion.

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