Technology Transfer for Sustainable Housing in Sudan

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Abstract

Shelter comes in the second place, following the need for food, as a priority for human beings (Windapo \textit{et al.}, 2004). The shortage of adequate housing is prevalent in most countries over the world (Kateregga, 1983) like the situation in African countries where demand has always outstripped supply. The demand for housing is more critical in the main urban centers (Hammond, 1983) resulting in an extreme imbalance in the rural-urban population ratio (Tackle, 1983).

The Demand for sustainable construction, and especially for housing, is likely to increase as the population increases. The insufficient supply of adequate housing is attributed, among some other factors, to the high costs of construction and building materials. Accordingly, investigating the problems of building materials and components for housing might contribute to availing adequate housing. Sustainable building technologies and construction techniques are crucial in the context of exploring the building materials industry for housing.

International technology and knowledge flows (ITKFs) are employed as boosting mechanism for the development of industries and countries (Ègmond, 2004). Therefore, the purpose of this paper is to highlight the role that technology transfer and technology diffusion might play in developing the building materials industry on sustainable bases in Sudan as a developing country. The focus of the paper will be on the technology transfer in the housing sector in the context of building technologies through innovative materials and construction techniques that comply with the requirements of sustainable developments in economical, social, environmental, and technological terms.

The authors relied on literature review to highlight the importance of technology transfer and innovation in developing the building industry with its formal and informal sectors. Three case studies are presented to draw an image of the application of technology transfer and diffusion of knowledge in building for housing in the Sudan.

\textbf{Keywords:} Sudan, Housing, Building Materials, Technology Transfer, Building Technology
1 Introduction

The population growth and high rates of urbanization put more pressure on the provision of adequate and affordable housing and add more challenges to urban problems. In developing countries, where the informal sector dominates in the provision of housing for middle and low income classes (de Bustillos, 2007), building materials represent one of the main issues to be considered. (Wells, 1999) stated that small enterprises and individuals, self employed workers have always been important in construction, and in developing countries they have traditionally undertaken much of the work of house construction, maintenance, and repair. (de Bustillos, 2007) refers to houses developed by the informal sector as “Engineering without Engineers”.

Similar to many developing countries, Sudan is faced by inadequate capacity and inefficiency in the building materials industry. Lack of capacity could be attributed to: lack of required infrastructure, lack of finance, lack of production facilities, lack of skilled labor, and lack of education and training programs. The search for alternative materials and building technologies affordable for the middle and low income classes is assumed to be one of the possible solutions to the urban housing as for rural housing too. Knowledge and technology transfer could be employed as means for the provision of affordable technologies and building materials products.

The purpose of this paper is to highlight the possibilities of adopting the concepts of knowledge and technology transfer to the building sector for housing as alternative solutions for the urban housing problems in a sustainable manner. It suggests that technology transfer could be employed for the purpose of enhancing the capabilities of the building sector for housing in Sudan.

2 Methodology

The discussion in this study is based on literature review and case studies. The available literature provides the definitions for technology transfer and related terms. Besides, the literature highlights the role of the technology transfer in sustainable construction, the factors affecting its success, and the difficulties that face its application. The paper provides three case studies that introduce innovative building technologies for housing in Sudan. The review and analysis of the three case studies are based on interviews with the providers of the innovative technologies subject to the study. Two of the three case studies show the role of Non-Governmental Organizations (NGOs) in the process of transferring building technologies and their application. Two projects developed by Practical Action (an international NGO working in Sudan), are taken as examples. The third case study describes a technology that has been developed, individually, by a professional architect. The objective of these case studies is to show the role of technology transfer in the provision of sustainable construction for housing that responds to the immediate needs of the majority of population in the country that suffers famine, wars, conflicts, and natural disasters.
Sustainable Architecture and Urban Development

3 Literature Review

3.1 Innovation, Knowledge and Technology Transfer in the Building Industry

Innovation is defined as “Ideas or practices that are perceived as new” (Rogers, 2003). It is seen as a cyclic process that includes not only the invention of technologies, but also the diffusion in terms of flows of technologies and knowledge, adoption, application, maintenance, adaptation and incremental development (Egmond & Erkelens, 2008) & (Egmond, 2004). (Rogers et al, 2005) defined the diffusion as “the process through which an innovation spread via communication channels over time”. The diffusion is accomplished through human interactions and communication between members of a community of practice (Rogers, 2003). Technology transfer has been defined by (Rodrigues, 1985) as “the application of new technology to a new use or user for economic gain”, another definition produced by (Roger, 1972) states that technology transfer is “the process by which an organization adopts an innovation made by another organization”.

(Bakar, 2006) use the definition of technology transfer in construction as “the planned conveyance and acquisition of technological knowledge and technique during the implementation of international construction projects”. On the other hand, (Devapriya & Ganesan, 2000) provided a comprehensive definition developed by (Carrillo, 1994) as “the process whereby knowledge in some form is transferred from a person or organization that possess it (the transferor) to another person or organization who arranges to receive it (the transferee)”. On the other hand, Norton (1999) described sustainable architecture as a process that can be replicated. Replication involves diffusion of knowledge and technology. Moon (1999) argues that if the technology and the design are too expensive for the average person, they can never be sustainable because they will not be widely adopted.

For a society to acquire products and services, three options are available; (a) acquiring from abroad, (b) developing locally, or (c) acquiring the production process from abroad and produce locally. Options (a) and (c) involve an international transfer of technology ITT resulting in an increased technology status. In this context, technology transfer is defined as “any form of technology over space, across the borders, between institutions or within the same institution” (Egmond & Vries, 2002).

3.2 Technology Transfer and Diffusion for Sustainable Construction

(Singh, 2007) states that Sustainability in construction is all about following suitable practices in terms of choice of materials, their sources, construction methodologies as well as design philosophy so as to be able to improve performance, decrease the environmental burden of the project, minimize waste
and be ecologically friendlier. Accordingly, technology transfer could be considered as a tool to meet the requirements of sustainable construction.

Generally, international technology transfer can be used as a boosting mechanism for the development of industries and countries (Egmond, 2004). The role of globalization in technology transfer in construction for developing countries is significant (Bakar, 2006), (Egmond, 2004), (Egmond & Erkelens, 2008), (Ofori, 2000; 2006), and (Zawdie & Langford, 2000). By introducing and “adapting” already existing technologies, the country can experience the so-called leapfrogging effect and gradually catch up (Egmond & Vries, 2002). (Bakar, 2006) introduced technology transfer as a mechanism for overcoming the problems of construction industry in developing countries. Compared to industrial sectors, the construction sector may be less reliant on imported technologies because construction technology is rather local condition-specific and inherited from local traditions (Milford, 2000).

The dissemination of technology as new equipment and machinery is the most traditional type of knowledge flow in the innovation system within all sectors, is also very important in the construction industry. In addition, technology diffusion could be applied by using a variety of mechanisms including demonstration projects, professional journals, trade magazines, lectures, conferences and site visits, personnel mobility, and other formal and informal networks including professional associations (Milford, 2000). (de Bustillos, 2007) reviewed the role of educational institutions in the provision of technology and its diffusion to the community through demonstration buildings and training programs. This form of technology transfer is based on the transfer of knowledge from professional to community through the participation of the community itself “participatory approach”.

### 3.3 Important Factors for Sustainable Technology Transfer

Despite being promising, many technologies remain undersupplied and are not used in the market (Egmond & Erkelens, 2008). The real technology transfer takes place only in case the receiver can use, adapt, and maintain the acquired technology components on a self-reliant and sustainable basis (Egmond & Vries, 2002). In this sense, Singh (2007) stated “architecture that encourages the folk-traditions closely related to the culture and life of the people as it is really lived, rather than the alienation of styles borrowed from elite houses or foreign cultures in the name of fashion, is sustainable. Norton (1999) argues that sustainable architecture shouldn’t be defined solely as “buildings that will stay intact for a prolonged period”, but is also concerned with the search for and the promotion of building methods that people can go on using with the skills and resources available to them. Consequently, sustainable transfer of technology involves the adoption of new building technologies which work with rather than against, local skills, materials, culture, and climate.

Singh (2007) listed some examples for sustainable building technologies which have been developed in some specific places and time and applied later in
some other places. On the top come the compressed earth block technology which is widely used worldwide, because it represents a synthesis of traditional practice and modern technology. It is also benefitting constantly from scientific input. The technology was used traditionally in countries like France, Morocco, northern India and Tibet, and is today used with stabilizers in USA and Australia. Ferro-cement which was explored by Nervi of Italy 70 years ago is another example of building technologies which become commonly used worldwide. Additionally, the earth bag technology, which was developed by Nader Khalili, is now used all over the world to bring low-cost, self-help, eco-friendly, disaster resistant and affordable housing to people with otherwise very limited resources. Not only is the potential cost of his homes cheap, but they are beautiful to look at and live in, as well as being very environmentally friendly and energy efficient. However, Norton (1999) argued that one cannot classify a particular building technology as being "a sustainable architecture technology". But we can assess the potential of a particular process or material to make a valid contribution towards sustainable architecture in a given locality.

(Saad & Greenwood, 2000) stated that successful technology transfer depends on the subsequent generation of new knowledge (post-transfer application) and on the capabilities of the receiver of this application to react quickly and effectively to change. Therefore, a substantial level of "in-house technology" and scientific and technological infrastructure is required for the process of successful technology transfer (Saad & Greenwood, 2000) & (Milford, 2000). The non-existence of technological capabilities is seen as the major bottleneck for the appropriate selection, utilization and development of technologies. Due to the lack of a strong technology infrastructure with technological capabilities, a country may fail to use its scarce resources efficiently (Egmond & Vries, 2002).

In his research on the factors affecting technology transfer in construction industry in Malaysia, (Bakar, 2006) identified 4 groups of important factors, namely: the environment of host countries, the internal characteristics of the "transferee", the technology transfer program, and the type of technology.

Norton (1999) suggested the following criteria for assessment of sustainable architecture, and thus transferred building technologies:

- makes substantial use of locally available materials and local means of transport;
- uses resources that are available in sufficient quantity to satisfy a general demand and not damage the environment;
- does not depend on equipment that is not easily available;
- uses skills that can be realistically developed in the community;
- can be afforded within the local socio-economic context;
- produces a durable result;
• responds to and resists the effects of the local climate;
• provides flexibility to adapt to local habits and needs;
• can be replicated by the local community.

4 Technology Transfer in Building for Housing in Sudan

The role of technology transfer in the building industry in the Sudan seems to be weak. Very few institutions are concerned with the investigation of new technologies or the diffusion of tested and effective technologies. The Building and Roads Research Institute (BRRI) at the University of Khartoum is a key player in the area of building technologies. The private sector firms are reluctant to invest in such researches. However, some non-governmental organizations and individual professionals contribute to investigating innovative technologies and their diffusion. The research in building materials and building technologies started before a couple of decades. However the quality of the work performed was not that good and even the good results were not diffused successfully.

The participation and contribution of NGOs in Sudan in the innovation and diffusion of new construction technologies are limited. Individual architects and engineers might have a greater role in technology diffusion, while they have a limited contribution to the innovation of the technology itself. To throw a light on the technology transfer in building technologies in Sudan, this paper reviews three case studies where sustainable technologies had been adopted and diffused. Two of these cases review projects undertaken by a non-governmental organization while the third is an example for the role of individual architects and engineers in the invention and diffusion of new building technologies which are believed to be environmentally sustainable. Addressing such attempts might open the gate towards sustainable construction technologies and practices through the application of environment-friendly materials and technologies. Besides, the adoption of technology transfer approaches could be employed to develop the local capabilities in a sustainable manner where successful practices are adopted, applied, and developed.

4.1 Technology Transfer in Building for Housing in Sudan: The Role of NGOs (Practical Action)

4.1.1 Introduction

Practical Action which is previously known as Intermediate Technology Development Group (ITDG), came to Sudan in 70s to provide technical assistance to the regional government in Southern Sudan for building reinforced cement boats, now it is known as Practical Action. Practical Action Sudan operates out in 4 field offices, El Fashir in North Darfur and Kassala in Eastern Sudan, Eldamizeen in the Blue Nile State, in addition to the Khartoum Head Office. The connection between all these fields is to improve human’s life and provide their basic needs. Practical Action’s Vision is of a sustainable world free
of poverty and injustice in which technology is used for the benefit of all. The Mission of the Organization is to use technology to challenge poverty by; (a) building the capabilities of poor people, (b) improving their access to technical options and knowledge, and (c) working with them to influence social, economic and institutional systems for innovation and the use of technology.

4.1.2 Sources of Technologies & Transferring Mechanism

One of the prime objectives of Practical Action is to be known as a leading authority on the use of technology to reduce poverty in developing countries. Practical Action Sudan exploits different sources for new technologies and innovations including: local innovators, inventors, indigenous knowledge, universities and academics, the private sector, staff within Practical Action, international networking with similar organizations (i.e., BASIN, Sudanese Technology and Innovation Network for Poverty Reduction (STINPR), and (Promoting Local Innovations (Prolinnova). Practical Action works in collaboration with any of the above parties and the end users of the new technologies themselves in a process known as Participatory Technology Development (PTD). The role of the organization in the diffusion of a newly acquired technology involves; research and development (R & D), feasibility studies, technical drawings, the building of prototypes and the testing of these prototypes in the field. If the new technology is proved to be successful, then it will be available for greater promotion and dissemination within areas where Practical Action operates.

4.1.3 Practical Action Experience in Transferring Technologies in Building

Since its establishment in Sudan, Practical Action Sudan has been participating in developing and disseminating many technologies in building and construction. Most of the projects performed by Practical Action had contributed significantly to the welfare of the targeted society. Besides, environmental concerns dominate the list of these projects priorities. The purpose of Practical Actions goes beyond just solving an immediate need of a special society. For instance, involving the community and transferring the know-how of introduced technologies guarantee the sustainability of introduced technologies in terms of proper absorption and application. Examples of the projects performed by Practical Action are;

Brick–making in Shambob in Kassala in Eastern Sudan

Together, ITDG and the brick-makers researched new techniques: fuelling their kilns with organic residues such as cow dung and bagasse (waste from the local sugar industry), improving the moulding and drying of bricks, and installing a new more efficient kiln. Demonstration buildings convinced the community that the technology could work.

A low cost and zero energy design school in Kassala
The project succeeded in promoting tested ‘zero energy’ models for building schools at reduced cost by 30% compared to other classical construction techniques, see fig (1).

Figure (1): Zero-Energy School in Kassala

Low cost house model in Kassala- Ferro Cement Vault Roof Technology

The project drew concerns to the problems of housing for low income groups. For the purpose of lowering the costs of building and to make shelter more affordable, a new technology for roofing was introduced through demonstration models.

Timber-Less (Domed Roof) House in Northern Darfur

The purpose of this project was to avail a shelter for the Internally Displaced People (IDPs) who fled the conflicts areas in Northern Darfur.

4.1.3.1 The Timber-Less (Domed Roof) House in Northern Darfur

Upon their return back to their original villages, returnees are going to face numerous difficulties, the most significant of which will be the mass destruction of local infrastructure and homes. To assist the IDPs, upon their return, in building permanent houses, the timber-less house (fig 2) was developed to overcome the problems of building materials availability, lack of skilled labor, and the environment which has been exhausted and deteriorated with wood also being used in vast quantities for brick burning. The organization introduced the mud dome house as an alternative house for the returnees instead of timber.

The same technology was disseminated under the name “Woodless Construction Programme” in West Africa in Burkina Faso, Mali, Mauritania and Niger as a response to the declining availability of organic resources used in construction. Over the years, through training and demonstration, skills have been developed to ensure technical and organizational sustainability: local builders use the "Woodless Construction" techniques and their acquired skills to build for their own local clients using local resources (Norton, 1999).

The house was circular of two meters radius, and the mud was used for both the walls as well as for the roof. The organization held many activities as part of the project and acquisition of knowledge and skills. These activities included:
• **Survey:** in 2006 in Abu Showk IDP camp in Al Fashir to identify building designs and types of materials used by the IDPs in their home villages.

• **One day workshop:** convened in El Fashir in the beginning of 2006. The participants were 56 persons representing government institutions, local NGOs, INGOs, UN agencies and IDPs community leaders.

• **Training program:** consisted of theoretical and practical parts to help the returnees building permanent houses depending on local materials, labor, and skills. To this effect 70 trainees were selected and received training for 21 days on alternative building designs and building materials. The training finished with the completion of four demonstration housing units which were different in design and utilized different building materials. Through this technical training period in construction of this timber-less house, some of the trainees gained the skills that assisted them in creating job opportunities that provide a source of income. Such training programs ensure a sustained level of acquiring knowledge and practice.

• **Construction Stage:** The construction of the demonstration model involved: site preparation, brick making, marking the foundation, building the foundation, building the walls, building the arches for doors and windows, using the steel ring, plastering the base (cement sand), the Nubian Domed Roof, plastering the roof (sand & asphalt), plastering the walls on the outside (sand & mud or lime), plastering the inside walls (sand & gum Arabic), the floor (sand), assembling the doors and windows.

![Mud Brick](image1.jpg)  
![Mud dome house](image2.jpg)  
![The use of the mud in the walls](image3.jpg)  
![The final form of the Timber-less House](image4.jpg)

Figure (2): The Construction of the Timber-less House
4.1.3.2 Ferro Cement Vault Roof Technology

The project is carried out as part of the efforts of Practical Action Sudan in improving shelter in Kassala in the camps for the IDPs. It focused on cheap or low-cost housing through minimizing the amount of materials and costs. It used the commonly available, energy intensive materials like cement and steel but in a highly efficient manner thus saving scarce material resources. With an ability to be cast into thin shell elements, Ferrocement opens possibilities which are not possible in conventional brick and concrete (Singh, 2007).

To involve the target group in the project implementation, Practical Action helped in the establishment and formation of Sawa Sawa and Kada Self Help Groups for housing. A model, composed of two bedrooms, kitchen with lobby and a verandah, was built. A participatory approach had been followed to reach a consensus on the agreed upon model, the following points illustrate how the model had come into being:

- **Two workshops**: in 2002 addressed adequate, appropriate and affordable housing issues. The participants of the workshop included; concerned governmental institutions, academic institutions, non-governmental organizations (NGOs), community based organizations (CBOs), civil society organizations (CSOs) and private sector.

- **Market and quantity survey**: had been conducted to ensure the viability of the vaulted roof compared to the traditional roof (balady).

- **Participatory approach**: a set of alternative designs: were discussed thoroughly with the community members, artisans, builders and local consultants from Kassala town. Besides, the community was engaged in the production of local building materials.

- **Training**: 21 builders were trained to establish their work to build this new design.

- **Demonstration**: Two houses were demonstrated as new type of housing in Kassala (fig 3).

![Figure (3): Vault Roof House in Kassala](image-url)
The Project Outcomes are summarized below:

- Establishment and formation of Sawa sawa and Kada Self-Help Groups for housing to: (a) facilitate the establishment and strengthening of Self-Help Groups for Housing as a self-financed housing groups, (b) enable poor people and marginalized urban dwellers to advocate and seek support with respect to shelter, land tenure, environment, income and employment, (c) enhance maximum degree of financial self-sufficiency and good governance, and (d) provoke local knowledge and social capital encouraging the community towards congenial housing scheme.
- Building of core houses by engaging the community and experts at all stages.
- Technical and managerial trainings which improves the local technical knowhow.
- Knowledge and information sharing to disseminate the demo-house model and to share experience and disseminate knowledge.

4.2 Technology Transfer in Building for Housing in Sudan: The Role of Private and Individual Architects (Dr. Osman Elkhair)

Private and governmental construction companies have a great responsibility towards the transfer of the construction technologies in general, since it has a direct contact with the clients and community members. Dr. Osman Elkhair, as an owner of one of the private construction companies in Sudan, has a role on innovation of new construction technologies. The Swedish Roof technology (fig 4), which was firstly employed in the Swedish house in the International Park in Khartoum, is one of his major inventions. It is similar to the Jack Arch and the Libyan Arch because all of them are combined constructions; concrete and iron or brick and iron. The Swedish roof consists of two layers of iron mesh with iron bars with a length that varies according to the total span which is not fixed and depends on the design. A layer of brick is laid in the area between the two iron wire mesh with an external and internal layer of plaster as a final finishing layer. One of the characteristics of the brick is that it is a high thermal mass which delays the heat transfer during daytime making it suitable for the climate of Sudan. Dr. Osman also contributes indirectly to the technology transfer and diffusion by encouraging three of structural engineers who are working as local contractors, to transfer some of his construction technologies through their own private projects, so they participate in some way on the technology transfer and also in diffusion.

In Sudan few publications highlighted new innovations in construction like the Swedish roof, and this is, to some extent, one of the reasons that hamper the transfer of and awareness about the new technologies. The Swedish roof, as an invention, was published in only one magazine, namely the Building and Roads Research Journal, which had been the only documentation for this innovation. Another method that is of benefit in transferring the technology was made
through training local contractors who absorbed, applied, and developed the technology through their projects.

4.3 Problems of Technology Transfer in Construction in DCs

The problems that might probably be hindering the process of transferring successful technologies in building to developing countries are manifold. The construction industry in the Sudan, including both the formal and the informal sectors, is faced by many of these problems some of which are:

- The weakness of or even non-existing linkages between the enterprises in construction industry and various agents. Therefore, technological capabilities building takes place on non-durable basis and gets easily lost when it is not further diffused and assimilated (Egmond, 2004).

- The deficiencies of physical infrastructure (communications and transportation, energy, and water supply networks) in many DCs (Egmond, 2004).

- Low investment in training, education, and R&D (Milford, 2000).

- Local firms lack the technical and managerial capacity for designing, developing, operating and implementing projects which avail the opportunity for technology transfer to take place (Zawdie & Langford, 2000).

- The tendency of foreign contractors to adopt strategies which do not support host countries (Ofori, 2000).

- The neglect of building local technological capabilities by developing countries which seriously affect their ability to employ the imported technologies effectively and efficiently (Milford, 2000).
• Technology transfer in building with local materials and building technologies (i.e., earth) is hindered by the association of these materials with poverty and low-socio-cultural status as a symbol of low societal status (Baiche et al., 2008).

• Lack of linkages between the informal sector construction activities and the agents in the formal innovation system of the construction industry (Egmond, 2004).

• Local contractors, in order to avoid risk and keep their reputation, are reluctant to apply and adopt new technologies unless these technologies are wide-spread and turn to be successful.

• In self-help projects, the owners are reluctant to expose themselves to the risk of applying new technologies. In contrary, they prefer applying the traditional technologies they practiced for decades or technologies they tested by themselves even if these technologies turn to inappropriate.

• The shift towards producing the machineries and equipments used in the technology before the absorption of the technology itself leads to the failure of the technology.

5 Conclusions and Recommendations

The adoption of technology transfer and dissemination of successful technologies in building for housing might be seen as a possible solution for availing adequate and sustainable housing. The role of the formal sector in construction in this regard is indispensable. NGOs in Sudan have some contributions to solving the problems of housing for IDPs by introducing innovative materials and technologies based on local resources. Despite the role of individual architects and researchers in introducing innovative materials and technologies, manifold problems hinder the transfer of these successful technologies. Lack of coordination between stakeholders in the construction industry comes on the top of these problems. Most types of buildings which are developed using local materials and technologies are considered appropriate solutions to the housing problem in most rural, urban, and suburban areas all over the country. It could be promoted by many indigenous and foreign organisations, architectural institutes, ministries of planning, and architectural firms. Besides, different mechanisms of transferring technology could be employed to enhance and maintain knowledge sharing in construction and building industries. Building capacity and improvement of basic infrastructure are perquisites for a successful transfer of international knowledge and technology. The following recommendations are paramount to the adoption of sustainable, durable, and more effective transfer of technology for the construction industry in the Sudan:
• Bridge the gap between the research institute and the industry through the application of tested technologies on real projects.

• Invite NGOs, CBOs, and CSOs to participate in the development and dissemination of new technologies and practices that comply with the sustainability parameters in terms of economical, sociological, environmental, and technological aspects.

• Encourage the private sector which dominates the scene of the construction industry in the Sudan to invest in research on, adoption, application, and diffusion of successful technologies.

• Encourage local contractors and practitioners to adopt and apply tested technologies that fulfill the sustainability requirements.

• Organize workshops and public events to introduce new and successful technologies and new materials.

• Raise the skills' level of the craftsmanship through training and involvement in projects that introduce new technologies and practices.

• Adopt the participatory approach through the involvement of the community, in testing, introducing new technologies, or the development of existing ones.

• Assessment of transferred technologies and the level of their contribution to sustainable construction practice.

• Dissemination of successful technologies, given the specialties of and availability of required resources, in different regions of the country.

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Facing the Construction Industry in Developing Countries”, 15th-17th November, Gabarone, Botswana


