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Opportunities and challenges in the development of smart cities in Tanzania

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Abstract. In developing countries especially in African continent, rapid population growth in cities is a major concern. Majority of governments in Africa have made more effort to develop urban areas as compared to the rural ones. Social and economic activities are more concentrated in urban areas. This is a pushing factor for the rapid population growth in cities as many people, especially young generation, tend to migrate from rural to urban. This growth leads to excessive exploitation of natural resources, environmental degradation and increased pressure on social services. Rapid increased population acts as an encouragement to construct smart cities for achieving needs for present and future generations. Tanzania as one of the developing countries in Africa has taken initiatives in establishing smart cities. The aim of this study therefore, is to examine opportunities and challenges in the development of Smart cities in Tanzania with a case study of Mbeya city. In addition, conceptualization about development of smart cities is proposed to prioritize the planning of smart grid among other smart city infrastructure systems. Conclusively, Mbeya city has a full potential of many strengths and opportunities for successful development as a smart city.

Keywords: smart city; smart grid; smart city infrastructure; SWOT analysis; renewable energy

1. Introduction

Energy is a fundamental requirement for socio-economic aspect of any country. Social and economic activities are dependent on energy. Amount of energy consumption indicates level of development of a nation. Developed countries normally consume higher energy than developing ones. Sustainable energy is required for supporting sustainable development (Omer 2008).

Development of smart grid counteracts challenges which are related to immense growth of urbanization caused by increased rate of urban population. The growth has increased global concern of excessive exploitation of natural resources. Energy resources, for example, have negatively affected an environment through greenhouse emissions (Planning Commission 2011). Developing world is prone to increased population in forthcoming few years. There is high pressure of bringing good quality of life through smartization of conventional cities. Suitable approach for use of energy sustainably, electricity in particular, is developing smart grid to supply

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smart cities, which requires smart infrastructures. These infrastructures are all supplied by smart grid. Urbanization in developing countries is not properly coordinated thus existing infrastructures in normal cities are not smart where traditional grids also prevail.

All these infrastructures in ordinary city need transformations (Schaffers *et al.* 2011). However, early planning stages of all infrastructures should reflect or tied to the plan of smart grid for the reason as they are electricity dependent.

Access to modern energy services especially electricity has been a global concern. There is a low access to electricity in developing countries (Armaroli and Balzani 2007, Winkler *et al.* 2011). However, due to the intensive investments in economic activities, rapid growth of population and enhancement in living standards are the main reasons that lead to high rate of energy consumptions (Chen *et al.* 2008, Omer 2008). These reasons do not take place in developed countries where economic activities are in equilibrium, the population growth is slower from family planning, and high standard of living has been attained (Wilson and Purushothaman 2003)

Rapid increase in energy consumptions has negative impacts on depletion of resources, political instability and environmental pollution (Ehrlich and Holdren 1971, Homer-Dixon 1994, Omer 2008, Omri 2013, Wackernagel and Rees 1998). In traditional electric grids, energy produced is wasteful from less efficient appliances and manual automation mechanisms (Chilamkurti *et al.* 2009, Saidur 2010). Therefore, amount of energy generated is not fully utilized with a substantial loss in energy resources.

The exacerbated energy consumption and power loss are minimized by introduction of energy conservation and efficient energy measures. These measures are vital for avoiding excessive extraction of energy resources and for ecological protection. In order to reduce the accelerated energy consumption and to eliminate its consequences, there is a need to employ smart energy management systems based on ICT devices; renewable energy technologies and energy efficient appliances. This type of management system is possible with a system known as smart grid. Smart grid can be defined in several ways from different organizations. According to department of energy of United States of America (USA), smart grid is defined as a new approach of transporting electricity from electric power generating source to end-users via computerized systems which employ to-and- fro communication technology (Lee *et al.* 2012). Also, according to the International Energy Agency (IEA), smart grid is defined as an electric network which employs digital and innovative technologies for monitoring and managing the conveyance of electric power from given electricity generating sources to meet the changing load demands for customers. Energy demands and capacities of whole electric power generating sources, power grid personnel, consumers and other stakeholders of energy market are organized through smart grid for effective and efficient performance alongside with minimization of costs and environmental pollution (Lee *et al.* 2012). Development of existing power grids in developed and developing countries in necessary and therefore application of smart grid is different levels in both groups of countries. However, expansion of smart grid technologies in developing world has a lot of complications and challenging aspects which can hinder the support and implementation from the governments (Nejad *et al.* 2013).

This new paradigm of generating electricity employs renewable energy-based distributed generation system using renewable energy sources (RES). Integration of RESs in smart grid improves efficient and they are both economically and environmentally feasible (Lee *et al.* 2012). Feed-in-tariff (FIT) is among other important renewable energy-related policies implemented for gaining benefits of generating electricity via RES. However, FIT is fixed and thus failing to comply with dynamic electricity market. RES split model has been proposed and then be

introduced in a traditional market. The market and RES producers are aggregated by means of virtual associations (VAs) which are dynamic group for prosumers via ICT. VAs promotes electricity generation using RES by supporting active participation, high profit and fair competition among the stakeholders. Rank-based fair sharing policy has been proved to increase participation and provides substantial incentives for prosumers (Doulamis *et al.* 2017). ICT plays a great role of smart energy management in a smart electric power network such as smart micro grid, smart grid etc. Conventional meters transfer electric power in one direction of power system. The introduction of distributed generation in conventional grid causes power flow in two opposite directions. This introduction causes technical challenges needing restructuring of conventional grid by employing smart meters for remotely measuring power consumption and billing purposes (Nejad, *et al.* 2013, Gandhi and Bansal 2013). Smart meters mostly use a two-way communication technology via radio frequency (RF) network technology by which different communication networks such as local area network (LAN), metropolitan area network (MAN), wide area network (WAN) and home area network (HAN) can be formed (Nthontho *et al.* 2011, Gandhi and Bansal 2013). Advanced metering infrastructures (AMI) system is appropriate for smart energy management (Gandhi and Bansal 2013). However, most of advanced metering infrastructures (AMI) are not standardized as are made by different manufactures so they need proper standardization for effective smart management. This increases the flexibility and interoperability of interfaces in AIM system. There are various interfaces for standardization of AMI systems from different levels of communication networks. Special organs should be instituted within the country for establishing AMI standards for better energy management (Nthontho *et al.* 2011). Different countries starting from developed to developing ones make development of smart cities. Studies have been and are continuously being conducted to develop smart cities. Smart city systems are vital for creation of smart city. Smart city infrastructure framework consists of smart house, smart transportation, smart social services systems, and smart waste management. These studies from different places have attempted to discuss about the socio-economic benefits, challenges, strategies in respect of development of smart cities (Mahizhnan 1999)

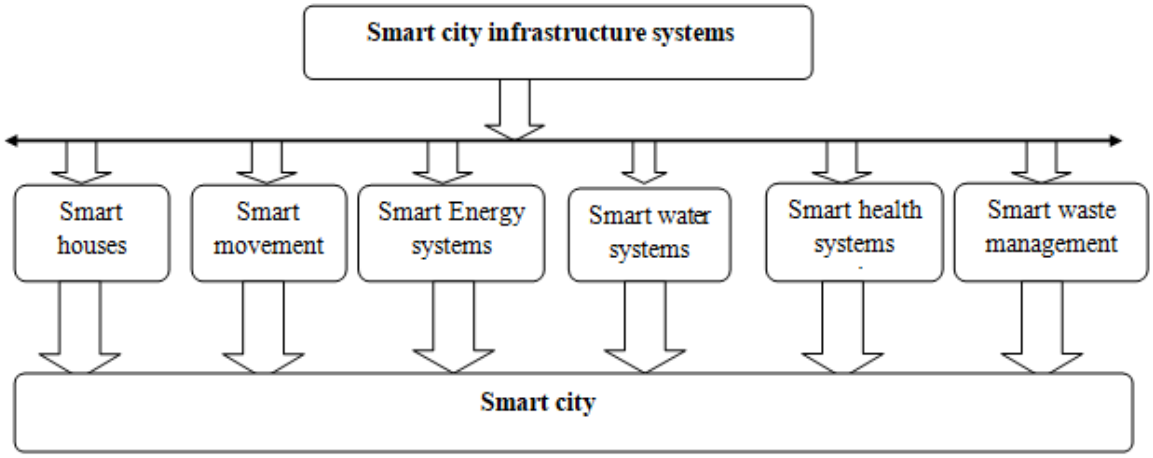

Fig. 1 Block diagram for traditional development of smart city development

2. Description of study area

The rate of growth of urbanization is a global concern. The number of urban residents has been increasing higher than the rural population since 2008. It is approximated that within 20 to 30 years developing world will be highly populated in cities with more concentration in countries of Africa, Asia and Latin America (Panel Consumption & Branch 2011, Revi and Rosenzweig 2013). There is no doubt that countries from low-income groups will be more populated than industrialized countries. Negative impacts of rapid population are increased use of energy, greenhouse emissions, expansion of urbanization to rural, increased demand for water, food, building materials and waste management. Rapid urbanization has generated challenges in terms of planning, improvement and operation of cities (Tahir and Malek 2016). Tanzania as one of the countries from African continent has experienced high rate of urbanization growth since its independence. African countries like Tanzania population increases from rapid growth of urbanization as governments tend to support more towns in development (Hope 1998). Mbeya city is rapidly populating as it attracts more people from the neighbouring regions and from countries like Zambia, Democratic Republic of Congo (DRC) and Malawi, as a business centre. As it has already been discussed about the consequences of rapid population in cities, Mbeya city is also in same line alignment. In addition, informal settlements are a result of increased population and informal land acquisition. The purpose of improvement of Mbeya city is to develop it as a smart city (Mohanty *et al.* 2016). Development of smart city in Mbeya city is assessed through using selected criteria within the frame of smart city infrastructure. Moreover, development of smart city infrastructure by priotization of smart grid has been also included.

Mbeya region is among other 31 administrative regions of United Republic of Tanzania. Mbeya region is located in southwestern highlands of Tanzania. The region consists of five administrative districts like Rungwe, Kyela, Mbarali, Chunya, and Mbeya. Before the division that took place in 2016, Songwe region was part of Mbeya region and it consists of Songwe, Ileje, Mbozi, Momba and Tunduma districts (Furuholt and Kristiansen 2007, Namwata *et al.* 2010).

Mbeya city is selected as a case study as it is one of the cities in Tanzania with a rapid growth. Mbeya city ranks fifth whereas Dar es Salaam is the largest city in Tanzania with a population more than two millions. It is located at geographical coordinates of latitude and longitude 8˚ 54″ 0‘S and 33˚ 27″ 0‘E (Michael *et al.* 2016). The population of Mbeya region was estimated to be at least 2, 707,410 out of which women were 1,409,672 equivalent to 52.1 percent and men were 1, 297,738 counting to 47.9 percent according to the national census in 2012. The population rate in the Mbeya city was 2.7 percent in 2012 (Magawa and Hansungule 2018). The city is also bounded by tourist places like Lake Ngozi, Kitulo Plateau National Park and Matema Beach in Lake Nyasa**.** The geographical location of Mbeya city is described in Fig. 2.

Numerous studies have been conducted worldwide on how to develop best smart cities. Therefore, different approaches from different countries have been used depending on localization of cities. Conceptualization that prioritizes smart grid and selected criteria for appropriate smart grid are used to identify opportunities and challenges for development and implementation of smart city in Mbeya city. Therefore, the aim of this study is to examine the development and implementation of smart city for Mbeya city by using strengths, weaknesses, opportunities and threats (SWOT) analysis method. Advantages of SWOT analysis are simplicity, low cost and multi applications such as health care, education, transportation etc. Shortcomings of SWOT analysis are, lack of clarity, makes interpretation of the results challenging, difficulties in grading of factors and subjectivity based on individuals bias (Phadermrod 2016).

Fig. 2 Location of Mbeya city in Mbeya region (Worldatlas 2019)

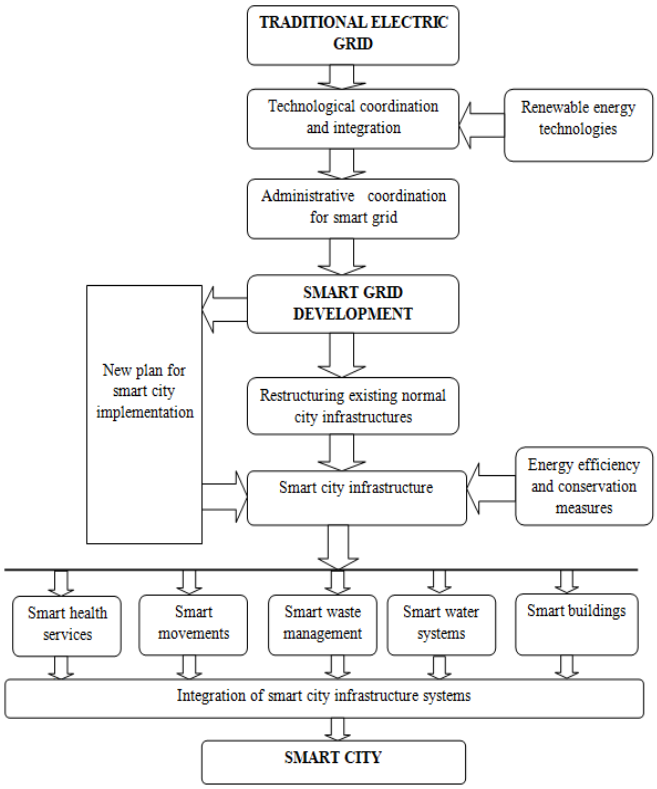

Fig. 3 Block for conceptualization

3. Methodology

For the benefits of simplicity and economic benefits, this study is conducted using SWOT analysis approach. Opportunities and challenges in developing smart city for Mbeya city are

identified. SWOT analysis is based on observations, reports, literature review and internet-based information. SWOT analysis is preceded by selection of criteria such as (i) Smart energy through smart grid (ii) Smart governance (iii) Smart information and communication technology (iv) Smart sustainable environment (v) Smart quality of life (vi) Smart human capital (vii) Smart economy and finance. A block diagram/ flow chart for the development of smart city is provided in Fig. 3. SWOT analysis is performed under selected criteria and its findings are also presented in the Table 1.

Table 1 SWOT Analysis for the development of smart cities in Tanzania (A case study of Mbeya city)

Features	Strengths	Weaknesses/ Limitations	Opportunities	Threats/challenges
Smart energy through Smart Grid	• Availability of human resource for designing and planning of the city. • Availability of electric grid from TANESCO. Estimated power for Mbeya region in 2020 is > 28.7 MW (MEM, 2016) • High potential of energy resource such as hydro, geothermal, solar, biomass, and coal .Available potential capacity in Mbeya region: Coal is at least 1OO MW and geothermal up to 100 MW (GPTL, 2013)	• Limited budget. There is financial limitation for grid extension from TANESCO (Msyani 2013). • Shortage of human capital of specialized field (Msyani 2013)	• Collaboration of power issues with neighboring countries • Good environment of investment as whole country	• The monopoly by TANESCO of generating, transmitting and distributing of electricity may hold back the initiatives of developing the smart grid in the city (Msyani 2013). • Global Technological evolution • Frequent outages from the national grid of Tanzania (Msyani 2013).
Smart Governance	• Awareness and inclusiveness of marginal groups. • Commitment to render social services in the city • Good leadership • Availability of universities may help Mbeya city in the aspect of planning • Accessibility to internet systems • Democracy through council of counselors of the city	• Less number of women in decision making organs • Limited budget in implementing the plans • Less participation of private sector in smart city development • More top down approach of leadership is more practiced than down up approach.	• Learning from other regions within the country and international levels. • Involvement in international platforms concerned with the development of smart cities	• Difficulties in planning due to rapid increase of informal settlements • Politics in multi system environment may cause unnecessary competitive leading to delay of development of smart city.

Table 1 Continued

Features	Strengths	Weaknesses/ Limitations	Opportunities	Threats/challenges
Smart Information and Communication Technology	• Accessibility and availability of ICT for innovation and learning Implementation of smart meters of money transactions for water and electricity services. Prepaid meters and communication technologies (Check *et al.* 2018, Nique and Opala 2014). • Improvement of economic capacity through agriculture, business , tourism and few industries by the use of ICT • Good weather for planting trees to reduce pollution.	• Lack of knowledge to use ICT for development purposes • Low technological capability. • Lack of utilization of ICT to avoid traffic congestions. • Lack of willingness to use the Tanzania and Zambia railway (TAZARA) to reduce the congestion.	• Tanzanian government initiatives to support information and communication infrastructure (Hamad 2018, Metfula *et al.* 2016). • Private sector participation or public-private partnership investment (Hamad 2018, Metfula *et al.* 2016).	• Rapid technological changes worldwide. • International economic competiveness
Smart Sustainable Environment	• Availability of high potential of renewable energy resources like solid municipal waste, solar, hydro, wind for electricity generation • Proper waste disposal through bins in the city and monthly cleanliness initiated by Tanzanian President John Pombe Magufuli. • Managing natural resources like within and around the Mbeya city like Kitulo national park and lake Ngozi • Application of renewable of renewable especially	• Deforestation for timbering and firewood • Lack of technologies and capabilities to convert solid municipal waste into energy • Informal settlements from sprawl growth	• More investment for affordable electricity • Allowing more private companies to provide affordable biogas for cooking	• Global warming

Table 1 Continued

Features	Strengths	Weaknesses/ Limitations	Opportunities	Threats/challenges
Smart Sustainable Environment	for cooking • Use of energy saver lighting lamps			
Smart Quality of Life	• Availability of open areas and cultural activities like Sokoine memorial stadium • Good environment of housing from local material and Mbeya cement company • Good health services with three major hospitals; Mbeya region, Mbeya referral and Meta hospitals plus number of dispensaries. • Educational institutions from kindergarten to university levels. • Attractive tourist environment • Inclusive health insurance schemes for example elderly people	• Facilities are not technologically integrated • Unplanned or informal settlements • Lack on technology in the country on smart buildings. • Designing issues in public buildings considering marginal groups especially disabled, elderly and women	• Involvement of private sector for improvement of different social aspects • Collaboration with international platforms concerning urban planning	• Safety issues in a highway for instance at Iwambi area • Interactions from neighbouring countries with Mbeya might cause social problems • In unplanned informal settlement is difficult to deal with fire issues
Smart Human Capital	• Initiatives by Tanzanian government of encouraging youths to study science, technology engineering and Mathematics • Mbeya regional library as a vital facility for education • Availability of education institutions like MUST, Mzumbe, Tanzania Institute of Accountancy (TIA), Saint Augustine University of	• No development of new curricula for development of smart city in all levels of education • Lack of skills for majority on how to use internet based systems • Limited budget and capability to research and development in local educational institutions	• Hiring expertise from international education institutions in specialized disciplines to support local institutions to develop the smart city • Collaborating with other countries in research and development projects on development of smart cities	i. Global technological changes ii. Economic competitiveness worldwide

Table 1 Continued

Features	Strengths	Weaknesses/ Limitations	Opportunities	Threats/challenges
Smart Human Capital	Tanzania (SAUT) etc. • Access to internet based systems			
Smart Economy	• Mbeya city is located in Mbeya region with high potential of agriculture • Mbeya city is the business centre for south regions and neighbouring countries like Malawi, Zambia and Democratic of Republic of Congo • Availability of a number of banks • Presence starting from small, medium to intensive sized industries • Good environments for investments • Tourism industry. • Mining industry.	• Low knowledge for majority on how to understand the market information from the internet based systems. • Apart initiatives from Tanzania government to support women economically. • Lack of spirit or knowledge about entrepreneurship among the youth and women.	• Good environment for investment in areas of tourism, agriculture, industries, trading, energy etc from local to international people • Expansion of business mark to neighbouring countries	• Regional and international business competition • Introduction of fake fertilizers by unfaithful business can affect agricultural economy

4. Conclusions

In SWOT analysis, conceptualization has been presented for developing through prioritization of smart grid infrastructure for successful development of smart cities. For the implementation of smart grid, the main challenge is the monopoly of TANESCO as TANESCO looks after all activities such as generation, transmission and distribution. Further, there is a lack of human resources in the development of smart grid concept at the selected site of Tanzania. Opportunities for developing smart grid hence smart city in Mbeya city are the availability of education institutions like Mbeya university of Science and Technology (MUST), Mzumbe University, Uyole Agricultural Institute, Tanzania Institute of Accounts, Open University of Tanzania etc.

Further, Mbeya has intensive strengths and numerous opportunities as have been displayed in the analysis. According to location of Mbeya city, collaboration with neighbouring countries like Zambia, DRC, and Malawi is essential for economic growth. However, access to ICT for majority of citizens, technological capability and rapid growth are also concerns of development of smart city in Mbeya city. Main limitations are limited budget for both planning and research & development. Among other challenges are rapid technological changes and economic competition

in regional and international levels. It is also recommended to utilize local institutions in development of smart city for Mbeya city; to continue collaborating with neighbouring countries for economic growth; to increase women participation in decision making process for smart development; to increase money for planning of smart city; to hire the specialized expertise regarding smart city from other countries and to increase training in ICT.

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