ISSN 1996-3386

Asian Journal of Industrial Engineering

http://knowledgiascientific.com

Knowledgia SCIENTIFIC
A Place to Publish Outstanding Research

OPEN ACCESS Asian Journal of Industrial Engineering

ISSN 1996-3386
DOI: 10.3923/ajie.2016.10.17

Research Article

Spatial Distribution of Electrical Infrastructures: Impact of Urban Sprawl in Lubumbashi, DR Congo

[1,2]Banza Wa Banza Bonaventure, [1]Kiseya Tshikala Flory and [3]Philippe Bouillard

[1]School of Industrial Engineering, University of Lubumbashi, BP 1825 Lubumbashi, Democratic Republic of Congo
[2]Centre de Compétences en Planification et Gestion Urbaine (CCPGU), BP 1825 Lubumbashi, Democratic Republic of Congo
[3]BATir Service (Building, Architecture and Town Planning), Université Libre de Bruxelles (ULB), Brussels, Belgium

Abstract

The rapid and unplanned expansion in sub-Saharan Africa was favored by high rates of overall population growth and this has led to the proliferation of low-income settlements in peripheries of many cities and this without extension of public services. This study was conducted in Lubumbashi city in order to highlight the spatial distribution of electrical infrastructures face to urban growth from 1996-2014. Four multi-temporal SPOT images of the city of Lubumbashi have been used to highlight the spatiotemporal dynamics of the city. On ground surveys led to geo-reference the electrical cabins supplying the residential sector. The survey results were supported and complemented by information (length of the electrical network, installed power) collected in the database of the National Electricity Company. The results showed that the city of Lubumbashi is expanding rapidly, while the increase in the electricity grid and the installed power rates are sharply down. Furthermore, the distribution of electric cabins between 1996 and 2014 did not follow the urban sprawl. The National Electricity Company SNEL with 57.8% of electrical cabins followed by privates (39.6%) and donors (2.4%) concentrates its activities in old neighborhoods, places sheltering the services of urban administration and important economic functions. While private and donors, despite their low impact are trying to expand their actions even in the new municipalities naturally abandoned by SNEL. Good urban planning, good management and a broad growth of power sector reform are the main ways to overcome this impasse.

Key words: Urban growth, electrical infrastructures, urban management, urban services

Received: February 01, 2016 Accepted: April 23, 2016 Published: June 15, 2016

Citation: Banza Wa Banza Bonaventure, Kiseya Tshikala Flory and Philippe Bouillard, 2016. Spatial distribution of electrical infrastructures: impact of urban sprawl in lubumbashi, DR Congo. Asian J. Ind. Eng., 8: 10-17.

Corresponding Author: Banza Wa Banza Bonaventure, School of Industrial Engineering, University of Lubumbashi, Lubumbashi BP 1825, Democratic Republic of Congo

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Overall, the rapid growth poses several challenges in urban planning and management (Yuan *et al*., 2005). In Africa, urbanization is seen as a process caused by poverty, not the socio-economic transition, induced by industrialization as has been the case in other major regions of the world (Un-Habitat, 2008). Urban growth of most African cities creates multiple problems associated with electricity access and other urban services (Chen *et al*., 2004). Presently, the average rate of electricity access in sub-Saharan Africa is 16% (World Bank, 2008; IEA., 2009). Since the 1990s, though the percentage has evolved favorably, the number of people without electricity access has increased because of population growth (World Bank, 2008; AFD., 2013). However, those African countries having their historic national electricity company today, present the highest electricity access rate: Ivory Coast 39%, Ghana 60% (82% in urban areas and 29% in rural areas), South Africa 70% (AFD., 2013).

Yet, energy is an engine for economic development. It is necessary for the creation and maintenance of industries, facilitates trade and services and simplifies communication and transportation systems (Electriciens Sans Frontieres, 2012). About 85% of energy needs in sub-Saharan Africa (excluding South Africa) are covered by wood, accelerating deforestation (IEA., 2004; World Bank, 2007a; Shuku, 2009). In this region, more than 500 million people don't have access to electricity (Clerici, 2007). Firewood cuts are estimated at 49.5 million tons (2002) and cover over 92% of energy needs (WEC., 2004; Hutz-Adams, 2008).

In Democratic Republic of Congo, national electrification rate is presently about 9% and only 1% if taking into account only the rural area (76.8% of the Congolese population). However, foreign firms exploit energy resources of the country (ADB., 2008). In urban areas, only 35% of the population has access to electricity, 8.9 million inhabitants distributed among 1.6 million households (UNDP., 2013). However, the National Electricity Company, "SNEL" suffers from many problems including outdated technical facilities, gaps in the company's management and bad morality of payment (agencies and state enterprises mainly do not pay bills) are cited (Hutz-Adams, 2008). Only 55% of bills in 2005, worth US $ 174 million, were payed (World Bank, 2007b). A survey by the World Bank with companies working in the DRC has shown that they are faced with 181.6 days per year to power outages (World Bank, 2007a; Hutz-Adams, 2008). Cable stealing qui increased due to high copper prices amplified thesis problems (Hutz-Adams, 2008).

The rapid growth of urban population in Lubumbashi led a surge in energy service demand. This often results in perpetual voltage drops and power cuts (Muhinduka, 2010).

Understanding the impact of urban growth experienced in Lubumbashi on electricity access is a very important fact since it allows: The highlight of the spatial temporal distribution of electricity grid, identification of the main actors of electricity sector. However, most researchers focused their studies on the importance of electrical energy for urban development and electricity sector management (Muhinduka, 2010). The link between urban sprawl and distribution of electricity infrastructure remains unsolved by previous studies. In Lubumbashi there is no literature to date highlighting the spatial and temporal distribution of electric cabs in relation to the spatio-temporal growth of the city. The main hypothesis in this study is that the spatial distribution of electrical cabins did not follow the urban expansion. In this study, SNEL interventions would be concentrated in older neighborhoods by focusing on affluent populations or important economic functions.

Located between 11°20'-12°00' South latitude and 27°10'-10'27° East longitude, Lubumbashi city is the capital of the former province of Katanga. Lubumbashi had 413,000 inhabitants in 1973-700,000 in 1988. Recently, the city counted 1,480,152 inhabitants in 2009 (Frauman, 2004; INS., 2009).

At beginning, the city was supplied with electric power by thermal power of Union Minière du Haut Katanga (UMHK). In 1930, connection to the interconnection network of hydroelectric power plants of Lufira was carried (Bruneau, 1987). The distribution was therefore ensured by SOGELEC (actually SNEL). As for urban growth, Lubumbashi is considered as a town exploded from a new population explosion under the double influence of natural increase and net migration supported by copper market explosion (Nsiami, 2009).

MATERIALS AND METHODS

Data: The first set of data used in this study consists of four multi-temporal SPOT images of the city of Lubumbashi, respectively recorded on 08/29/1996 (with three spectral bands and 20 m resolution), 16/07/2002, 18/06/2008 and 06/20/2014 (with four spectral bands and 10 m resolution). These images of great spectral quality helped to highlight the dynamics of Lubumbashi urban expansion (Banza *et al*., 2016). The second set of data is obtained from the terrain surveys. These surveys highlight the spatial distribution of electric cabs in the city of Lubumbashi.

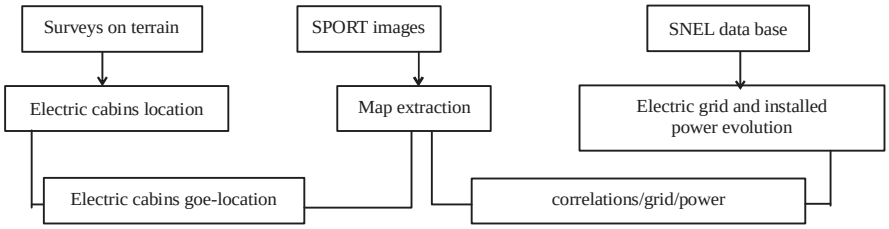

Fig. 1: Methodological approach

Location cabins: Lubumbashi includes 7 municipalities (Lubumbashi, Kenya, Kamalondo, Katuba, Kampemba, Ruashi and Annexe). Each municipality was visited in order to geo-locate electric cabs by using a GPS. Prior information on the location of each cabin and installed capacity per municipality were obtained from the municipal officials of SNEL. This information allowed browse all municipalities identifying operational electric cabs. For each electric cabin, the following information was collected: The geographic position (longitude and latitude, which allowed geo-situate all cabins on multi-temporal maps of Lubumbashi) and the implementation date of each electric cabin (which allowed situate temporally each cabin), the power of each cabin (which helped determine the capacity of an electric cabin to feed the population) and the owner of each cabin (which helped to distinguish cabins implemented by SNEL, privates and donations).

Methodology and data processing: According to Aguejdad (2009), methods based on photo-interpretation are sufficiently precise extraction methods and detailed urban objects useful in the field of development in general (Galicia-Mattic, 2005) and urban planning in particular (Lortic and Couret, 2003).

To highlight the spatiotemporal distribution of electric cabin in the city of Lubumbashi superimposed electric cabins on multi-temporal maps of Lubumbashi city (Fig. 1). This allowed to distinguish the electric cabin according to their years of implementation and see the trend of this implementation compared to urban expansion of Lubumbashi. Different correlations were made using Excel software between the urban area, the network evolution and the installed capacity (Fig. 1).

RESULTS

Spatio-temporal distribution of electric cabins in Lubumbashi city: Figure 2 shows the spatial distribution of the electric cabins in Lubumbashi city. These cabins are essentially intended to supply the residential sector. As a result, these cabins are highly concentrated in urban limits of 1996. Lubumbashi urban area in 2001 there were only 112 cabins. As for the urban area of Lubumbashi in 2008 and 2014 the installed electrical cabins represent only 39.2% of all cabins feeding the urban population. Indeed, Lubumbashi city experienced strong urban expansion, the spatial distribution of electrical cabins that fuel the residential sector does not follow the direction of urban sprawl. From 1996-2014, 45.6% of the cabins have been concentrated in the town of Lubumbashi and only 5.6% of the cabins are operational in the Annexe municipality (peripheral area covering the new neighborhoods).

It is clear from Fig. 2 that electrical cabins installed in Lubumbashi are either donations or private property or are installed by the National Electricity Company (SNEL). Private cabins, SNEL and donations represent 39.6, 57.8 and 2.4% respectively. Most cabins installed by SNEL are concentrated in the urban area of 1996. This number is considerably going far from city-center. Lubumbashi municipality alone accounts about 45.6% of electric cabs in the city.

The general observation of Fig. 1 shows that urban sprawl does not motivate the National Electric Corporation to develop new facilities and this led to non-uniform distribution of electrical installations in Lubumbashi. The lack of a good electrical service management policy that requires knowledge of the meaning of urban sprawl amplifies this phenomenon.

Regarding private cabins, the general trend shows that unlike cabins installed by SNEL, they tend to follow more or less urban sprawl of the city of Lubumbashi until 2002.

The results on years of commissioning of electric cabins in Lubumbashi have identified three periods: 1996-2001, 2002-2007 and 2008-2014 (Fig. 3). From all electrical installations of Lubumbashi city, 39.2% of the cabins were in use during the 1st period (1996-2001) and 39.2% during the 2nd period (2002-2007) and only 21.4% that were commissioned during the 3rd period (2008-2014).

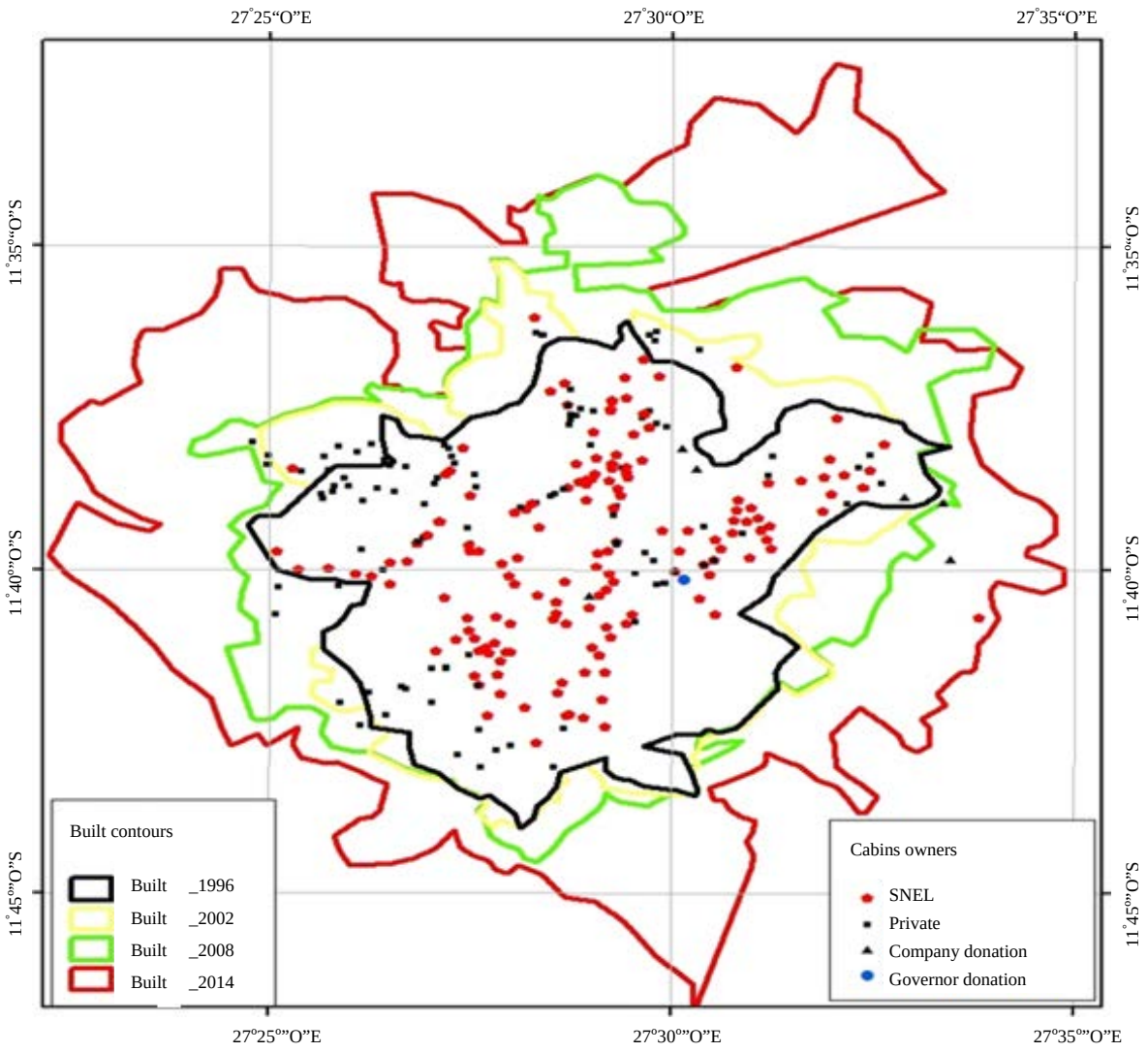

Fig. 2: Spatial distribution of electric cabins in Lubumbashi from 1996-2014

The trend shows that the number of cabins commissioned in Lubumbashi decreases over time, yet the city is rapidly expanding. A phenomenon deserves special attention, these electrical cabins commissioned between 2008 and 2014 instead of following urban sprawl, they are curiously concentrated in the same neighborhoods located in the urban area of 1996 especially for SNEL cabins (Fig. 2). The urban area of Lubumbashi has increased, the number of cabins has also increased, yet they have not kept spreading.

The temporal evolution of the medium voltage power grid is highlighted in Fig. 4. As a result, the power grid of the city of Lubumbashi had only 270 km in 1996, the length of the power grid increased by 39.1% in 2002. Although there is a correlation between the electrical network and the area built, it was observed that for an increase in built area of 100%, the electric network only increases by 43%. This implies that the increase of the electricity network is not solely dictated by that of the urban area between 1996 and 2014.

As for the installed power in the city of Lubumbashi, the linear regression between the built and installed power showed an area increase of 100% implies that of the installed capacity to 78.7% (Fig. 5).

The increase in the built area rate and the installed power of the electric network are shown in Fig. 6. As a result, growth rate of installed power and the electric grid are not proportional to that of built area. This implies that the built area of Lubumbashi city increases its growth rate over time, while increasing the electricity grid and the installed power becomes weaker over time. From 1996-2014 the growth rate of the electricity grid and installed

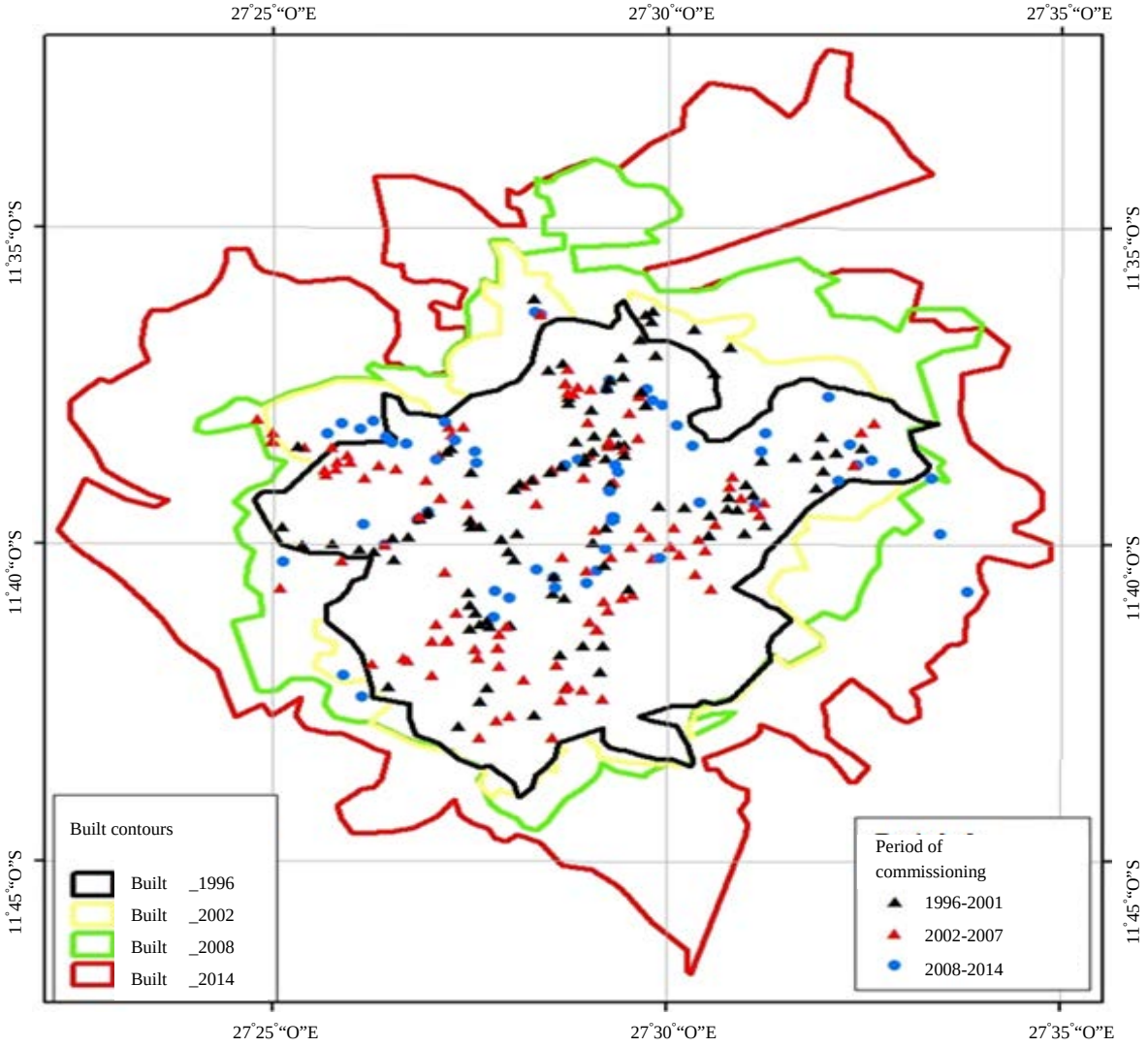

Fig. 3: Temporal distribution of electric cabins in Lubumbashi. Information on the commissioning date of each electrical cabin were found in the database of the National Electricity Company (SNEL). For SNEL and private cabins, information was obtained through terrain survey that allowed to interview the inhabitants of neighborhoods

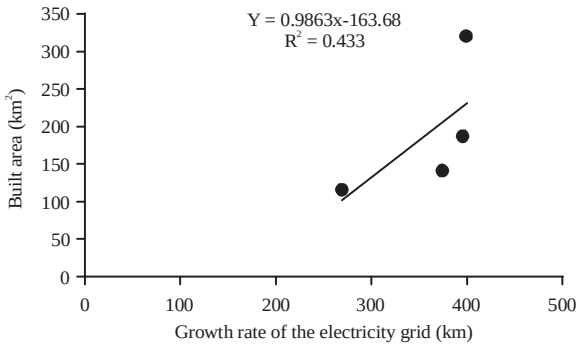

Fig. 4: Linear regression between the growth rate of the electricity grid and the built area. The information on the evolution of the electricity grid were found in the database of the National Electricity Company (SNEL). Data on the evolution of the built area was obtained through a study by Banza *et al.* (2016)

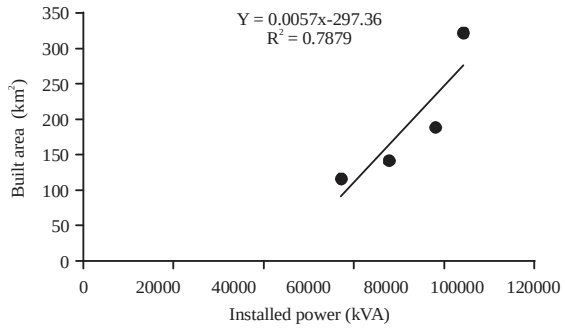

Fig. 5: Linear regression between the built area and the installed power. The information on installed capacity were found in the database of the National Electricity Company (SNEL). Data on the evolution of the built area was obtained through a study by Banza *et al*. (2016)

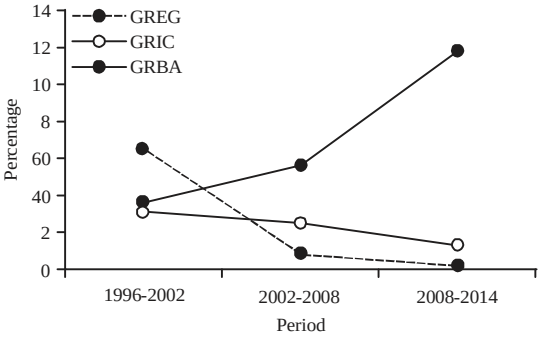

Fig. 6: Area's growth rate built, installed capacity and electricity grid during three different periods, GREG: Growth rate of the electricity grid, GRIC: Growth rate of installed capacity and GRBA: Growth rate of built area

capacity have been divided by 36 and 2 respectively, while that of the built area has multiplied by 3.

DISCUSSION

The result of the spatial distribution of electrical cabins intended to supply the residential sector is presented in Fig. 2. The general trend shows an irregularity in the distribution of electrical cabins. The location of electrical cabins determines the distribution of the electric grid in the urban area. Each cabin is characterized by its power and voltage. This irregular distribution of observed electrical cabins is considered as a consequence of a rapid urban growth combined with bad management of the electricity sector (Muhinduka, 2010). Urban growth in developing countries has created an unprecedented demand for electricity. Lubumbashi was no exception as it has experienced strong growth over recent years (Banza *et al*., 2016). This growth has led to strong demand for urban services such as water and electricity, (Hope, 1986; Steyn, 1994). In addition, Lubumbashi won large areas in recent years, the population also increased considerably (Banza *et al*., 2016). Alongside this urban growth, the electricity sector was during this same period, the subject of major faults: Antiquated technical installations, gaps in the company's management and unsystematic collection of bills (the organizations and state enterprises mainly do not pay the bills) are cited (Hutz-Adams, 2008). The superposition of the electric cabins on multi-temporal maps of Lubumbashi (Fig. 2) shows that most electric cabins (which supplies the residential sector) are georeferenced in the central part of the city. For cons, the peripheral part resulting from urban sprawl of 2002, 2008 and 2014 is largely non-electrified. Previous studies consider that, this phenomenon is due to unplanned urbanization (Muhinduka, 2010). In the case of Lubumbashi city, the central part comprises the oldest and concentrated urban administrative services and sometimes affluent populations. A set of processes lead to a disintegration of the network infrastructure and thus would promote fragmentation of the social and physical fabric of the city. Yet a non-uniform distribution of electrical infrastructure on the extent of the city would make possible circumvention strategies is to say strategies to connect users or valued spaces (economic and social criteria), skirting users and not valued spaces (Dementhon, 2011). For cons, the peripheral part of the city remains very less concerned with the actions of SNEL to serve populations into electrical energy. Furthermore, theft of electric cables more pronounced in this part of the city (due to the increase in copper prices) would have amplified the situation (Hutz-Adams, 2008). However, energy is not only the center of economic development, it is also at the heart of human development (Electriciens Sans Frontieres, 2012).

Lack of electricity cabins brings more difficulties for poor people living in cities and those living in rural areas and this is a real problem hindering the development (UNPD., 2008). In addition, the electricity failed for these poor people living in urban areas is more fatal compared to poor people living in rural areas (Electriciens Sans Frontieres, 2012). Apart from this core privileged by the electric sector, private actions have attempted to follow so little urban sprawl. This phenomenon would be motivated by private interests that find themselves in this context they see as a "Business". However, private and donor actions remain severely limited to cover the abandoned part by the National Electricity Company. Other reports and studies have attributed this to poor management of the National Electricity Company (Hutz-Adams, 2008; Katcho, 2009) and uncontrolled urban growth. Several reforms of the electricity sector involving the partial or total withdrawal government and segmenting the industry into three separate

units (generation, transmission and distribution) have been made in recent years in several African countries except in DR Congo (Katcho, 2009). Some authors attempt to reconcile private management and the fight against poverty (World Bank, 2004; Botton, 2005), while others take a more radical view by arguing that the various forms of commodification and privatization are inconsistent with universal coverage of the poor. Public and private supply systems are mainly criticized by the two positions according to two main objectives: The effectiveness of the provision at acceptable prices and inclusive and accountable governance, able to meet the demand of the poorest (Dementhon, 2011).

The temporal distribution of electric cabins in Lubumbashi has remained the same during the first two periods (1996-2001 and 2002-2007), where several cabins were commissioned. Unlike these two periods, the third (2008-2014) is marked by a decrease in electric cabins commissioned. Curiously, even the recently commissioned cabins are also concentrated in the "Electric core" of SNEL. Several articles have identified the obsolescence of certain equipment as the real problem in this issue (Muhinduka, 2010).

As regards the development of the medium voltage network according to the built area, linear regression shows that the network is weakly correlated with the expansion of the built area. For an increase in built area of 100%, the network for its part increases by only 43%. This implies that the grid does not follow sprawl (as shown above) but instead is concentrated in the core electric of SNEL. The installed capacity determines the energy power offered service for any use. However, the city of Lubumbashi shows an increase in installed capacity between 1996 and 2014 (Fig. 6). This power is not proportional to urban expansion. Figure 4 shows that the rate of increase of the electrical network (medium voltage) and the installed power is very low. Lubumbashi is subject to very contradictory situations: on one side it is experiencing very strong growth, on the other, the increase in the electricity grid and the installed power rates (which determine the possibility of access to electricity) decreased significantly. Nationally, the electrical deficit is rapidly increasing and projections had forecast a deficit of 840 MW power in 2015 (IEA., 2009). This deficit is actually much more important if one considers the significant demand not yet satisfied due to lack of investment in terms of extension of distribution networks, rehabilitation, maintenance and service production units and transportation (IEA., 2009).

The study highlighted two major challenges that accompany the process of urbanization in Lubumbashi. On the one hand, the study shows that the city of Lubumbashi is growing. The city spreads out more and more and the increase of urban population ensues. This should increase the demand for electrical service. On the other hand, inefficiency in the management revealed by the poor distribution of electric cabins suggests limited access to electrical service, especially for people living in the peripheral part of the city.

CONCLUSION

This study aimed to highlight the spatial distribution of electrical infrastructure in the city of Lubumbashi in connection with urban growth between 1996 and 2014. The city of Lubumbashi has experienced strong growth in recent years. Unlike electric infrastructure such as electric grid and cabins that are bankrupt. This study showed that the spatial distribution of electrical cabins determines the ability of people to access electricity. However, the observed distribution in the city of Lubumbashi is far from uniform across the city. Only the central municipalities of the city that are most electrified compared to suburbs. The main actor of the electricity sector (the National Company of Electricity) shows a large failure in the management and distribution of electricity. The most privileged places are those sheltering the great services of the city administration, important economic functions or old quarters. In the new neighborhoods, there are only a few electric cabins that belong mostly to private or and donors. Faced with this double situation of uneven distribution of electric infrastructure and rapid urban growth, the study comes to show the importance of integrated management between urban authorities in charge of controlling urban growth and those in charge to provide basics services to population. The observed situation shows a poorly managed urbanization and unplanned one hand and on the other poor management of the electricity sector in Lubumbashi. The possibilities to consider sustainable urban management is the effective urban planning accompanied by a reform of the electricity sector. Finally, a study that would highlight the socio-economic factors influencing access to electricity is a necessity for the establishment of a model adapted electric management.

ACKNOWLEDGMENTS

The authors thank the Académie de Recherche et d'Enseignement Supérieur, Commission de la Coopération au Développement (ARES-CCD) for funding the research that led to the realization of this scientific work.

REFERENCES

ADB., 2008. Energy and environment interaction. Energy and Environment Technical Paper Series, African Development Bank (ADB), Philippines.

AFD., 2013. Access to electricity in Sub-Saharan Africa: Lessons learned and innovative approaches. AFD Working Paper No. 122, French Development Agency, October 2013, Paris, France, pp: 1-102.

Aguejdad, R., 2009. Urban sprawl and evaluation of its impact on biodiversity: The reconstitution of the trajectories in the forward modeling. Ph.D. Thesis, University of Rennes 2-Upper Brittany, Rennes, France.

Banza, W.B.B., T.F. Kiseya and P. Bouillard, 2016. Dynamics of the urban area of Lubumbashi accommodate population growth between 1996 and 2014. In Preparation.

Botton, S., 2005. Privatization of urban services and serving disadvantaged areas: Social responsibility sharing. The case of water and sanitation services, electricity and telecommunications in the districts 'carenciados' of Greater Buenos Aires (Argentina) from 1991 to 2004. Ph.D. Thesis, University of Marne-La-Vallee.

Bruneau, J.C.L., 1987. Growth of urban space. Habitat dynamics. In Lubumbashi Atlas Pages 43-45. Centre for Geographical Studies on Black Africa.

Chen, X., X. Li and J. Ma, 2004. Urban change detection based on self-organizing feature map neural network. Proceedings of the 2004 IEEE International Geoscience and Remote Sensing Symposium, Volume 5, September 20-24, 2004, Anchorage, Alaska, USA., pp: 3428-3431.

Clerici, A., 2007. The inga development-what in the last 40 years, what in future. International Forum on Grand Inga Project, Gaborone, Botswana, March 16-17, 2007.

Dementhon, T., 2011. The governance of urban services networks: The case of electrical network reform of the Territory of the national capital Delhi. Urban Institute of Lyon, Addis Ababa.

Electriciens Sans Frontieres, 2012. Electrification project implemented in 2012. Activity Report.

Frauman, E., 2004. Peri-Urban Agriculture. In: Byakula, Socio-Anthropological Approach to Food in Lubumbashi, Petit, P. (Ed.)., Academie Royale des Sciences, Brussels, pp: 55-63.

Galicia-Mattic, C., 2005. Remote sensing for spatial analysis: Application to suburban areas to the urban area of Lyon. Ph.D. Thesis, Jean Moulin University Lyon 3, Lyon, France.

Hope, K.R., 1986. Urbanization and economic development in the third world: An overview. Cities, 3: 41-57.

Hutz-Adams, F., 2008. Energy and Water in the Democratic Republic of Congo. EED., Germany.

IEA., 2004. World energy outlook. International Energy Agency (IEA), Paris, France.

IEA., 2009. World energy outlook. International Energy Agency (IEA), Paris, France. http://www.worldenergyoutlook.org/media/weowebsite/2009/WEO2009.pdf

INS., 2009. Estimated population of DR Congo by province, city, district and commune/territories and area of residence. INS/Work DSDS-Document.

Katcho, K., 2009. Energetic sector, South Kivu province, shame, government observatory and peace. South Kivu, DR Congo, pp: 67.

Lortic, B. and D. Couret, 2003. Panorama Achievements and Interpretations. Variety of North/South Contexts: Cities Seen from Space. In: Symposium Pixels and Cities, Remote Sensing and Photogrammetry for Urban Development, SFPT., (Eds.)., Marne-La-Vallee, France, pp: 26-28.

Muhinduka, DK.D., 2010. Additive management, public goods and supply of electricity in the region of Bukavu, DR Congo. Ph.D. Thesis, Political and Social Sciences, Catholic University of Louvain.

Nsiami, M.C., 2009. Textural analysis of the image panchromatic Quick Bird very high spatial resolution. Application to the differentiation of land cover types Lubumbashi. Ph.D. Thesis, University of Lubumbashi, Democratic Republic of the Congo.

Shuku, N.O., 2009. Impact of the use of wood energy in the city province of Kinshasa in the Democratic Republic of Congo (DRC). Master Thesis, Quebec, Montreal.

Steyn, G., 1994. Restructuring the South African electricity supply industry. M.Sc. Thesis, University of Cape Town, South Africa.

UNDP., 2013. Sustainable energy for all in 2030, Democratic Republic of Congo. National Report.

UNPD., 2008. An overview of urbanization, internal migration, population distribution and development in the world. United Nations Population Division, UN/POP/EGM-URB/2008/01, 14 January 2008, New York, USA., pp: 1-34.

Un-Habitat, 2008. The State of African Cities 2008: A Framework for Addressing Urban Challenges in Africa. Un-Habitat, Nairobi, ISBN: 9789211320152, Pages: 206.

WEC., 2004. Survey of Energy Resources. Elsevier, London, ISBN: 9780080444109, Pages: 446.

World Bank, 2004. World development indicators 2004. The World Bank, March 2004, Washington, DC., USA., pp: 386.

World Bank, 2007a. Democratic Republic of Congo-country brief. The World Bank Group, USA. http://www. worldbank.org/en/country/drc

World Bank, 2007b. Enterprise surveys Congo Democratic Republic 2006. The World Bank Group, USA. http://www.enterprisesurveys.org/

World Bank, 2008. Designing sustainable off-grid rural electrification projects: Principles and practices. Operational Guidance for World Bank Group Staff, Washington DC., USA., November 2008, pp: 1-24.

Yuan, F., K.E. Sawaya, B.C. Loeffelholz and M.E. Bauer, 2005. Land cover classification and change analysis of the Twin Cities (Minnesota) Metropolitan Area by multitemporal Landsat remote sensing. Remote Sens. Environ., 98: 317-328.