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Research Article
Causes of Deterioration of the Electrical Service Quality at the Household Scale in Lubumbashi, DR Congo

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Abstract

Background and Objective: Recently, in Lubumbashi electricity consumption of households has increased significantly, which led the distributor to operate a load shedding in order to rebalance the grid. The main objective of this study was to identify the causes of the deterioration of the quality of electrical service at the household level in Lubumbashi. **Materials and Methods:** Surveys were conducted in different municipalities of the city covering 3440 households. Simple random sampling was selected. Quantitative data were subjected to one-way analysis of variance (ANOVA). In addition, a Tukey *post hoc* test was applied at the significance level <5%. Qualitative data were subjected to chi-square testing. The thematic maps were developed by superimposing the results of surveys on a vector map. **Results:** Of all the cases examined, it was reported that only the illegal connection and non-compliance of the facilities explain the deterioration in the quality of electricity enjoyed by households in Lubumbashi. In each municipality, there are cases of fraudulent connections yet to different degrees. Also possessing non-compliant installations explained in some areas of the city, the deterioration of the quality of electrical service. The majority, 41.2 and 82% rated the electrical service as very poor in the communes of Kampemba and Kamalondo, respectively. **Conclusion:** It was concluded that fraudulent connections and the non-compliance of domestic electrical installations are annoying factors in the deterioration of the quality service.

Key words: Lubumbashi, quality of electricity, illicit connections, deterioration, electricity consumption, load shedding

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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

More than 1.2 billion people in the world do not have electricity and another 1 billion have access to bad quality service[1]. Access to electricity is important to improve and meet the daily needs of households[2]. Its continuous supply is therefore crucial[3]. At the same time, the theft of electricity affects the distribution of electricity by overloading the infrastructure, which results in an interruption of the electricity supply[4]. In addition, the theft of electricity (illegal connections to the grid) can also lead to greater financial losses and make utility companies more difficult to estimate the load, which leads to power outages[5]. The consequences for domestic and industrial consumers are also important. Wild connections and frauds aggravated the inefficiency of modern energy systems. Two-thirds of sub-Saharan African countries are currently experiencing a crisis that cripples the electricity sector[6].

This crisis is the result of several factors: Strong economic growth and exponential population growth, which have led to a rapid increase in electricity consumption and urbanization, poor planning of the production and distribution capacities of the electricity and infrastructure maintenance. In this context already pointed out that the management of the electricity service in sub-Saharan Africa is characterized by load shedding or consumption restrictions to cope with the insufficiency of installed capacity[7]. In addition, illegal connections are very frequent and cause very significant losses on the grid. These losses obviously disrupt the transmission of electricity[8-10]. In recent years, it has been noted that the consumption of low-voltage electrical energy (LV) in the city of Lubumbashi has increased significantly. In fact, the share of electricity consumption in the residential sector of Lubumbashi which amounted to around 13.041 MWh in 2007 increased to around 50.225 MWh in 2017. This increase in consumption has caused major disruptions in the distribution thus leading the National Electricity Company (SNEL) to operate load shedding for a rebalancing of the grid. In addition, the population growth observed in the city of Lubumbashi is directly increasing the demand for electricity. Following this demographic growth resulting from rural-urban migration and natural growth[11], the city of Lubumbashi is experiencing a very rapid urban sprawl and a high densification of old neighborhoods[12]. Urban sprawl due to the proliferation of new neighborhoods is attributed to the need for less expensive housing, however the quests of basic urban services such as water and electricity leads to over-densification of old neighborhoods[13]. Urban sprawl implies an extension of the electricity grid while densification requires an increase in supply. The problems that arise from these 2 phenomena are multiple: The theft of electric cables, illegal connections and so on[12].

Regarding the quality of the electricity supply in Lubumbashi seen in terms of number of load shedding days per week showed that the municipalities of the center of the city benefit from a relatively good quality service with an average of 2 days of break/week unlike the communes and Annex Ruashi which are on the periphery (5 days of cuts/week)[14].

Several authors qualitatively describe the electrical sector in the world[15-23]. Given this situation, the causes of the deterioration of the quality of electrical service in Lubumbashi remain unidentified. The aim of this article was to focus on the quality of electricity service in relation to the mode of access to the electricity grid, the consumption of electricity and different uses at the household scale, which has not been done so far.

MATERIALS AND METHODS

Study area: The city of Lubumbashi is located at 27°29' S, 11°41' E. It is located in the south-east of the Democratic Republic of Congo and is the capital of the province of Upper Katanga (formerly Katanga). Its territory is the same as in 1957, landlocked in the sub-region of Upper Katanga and still comprises six municipalities with urban character and a peripheral annex, sub-divided into 43 districts, 246 cells and 1368 streets and avenues.

With a population of around[24] 1,500,000 in 2009 compared[24] with 1,200,000 in 2006, Lubumbashi is the second most populated city of DR. Congo after Kinshasa. In Lubumbashi[13], the growth rate of the population observed between 2001 and 2008 is 4.1%, while the various basic services such as electricity and water have not followed this increase[25]. This rapid growth of the population of Lubumbashi has resulted in the extension of the city and consequently a sharp increase in electricity needs. The building area of the city of Lubumbashi is increasing, the city extends to the periphery[14].

Data collection: The surveys were carried out among the inhabitants in the various constituent districts of the city of Lubumbashi. These surveys as a whole consisted in developing a questionnaire to facilitate interviews with household heads. The surveys were conducted throughout the city and lasted 10 months, from July, 2016-May, 2017. The questions were closed, the analysis of the answers also, the latter being encoded in a binary mode. These respondents were conducted according to the method recommended by Banza *et al.*[14].

Simple random sampling was selected as the sampling plan. Thus, a sample of 3,440 households were retained for

the entire city with an average of 80 households per neighborhood. For the representativity of the sample, the method used in this work is the quota method, which is the most used method to try to build a representative sample[26].

By taking a stratum of 80 households per district, the quota for the different municipalities depends on the number of neighborhoods in the communes. In addition, the size of the sample was estimated according to the formula recommended by Olivero *et al.*[27]:

$$n = t^2p(1-p)/m^2 \quad (1)$$

Where

n : The minimum sample size for obtaining significant results for an event and a set level of risk
t : Confidence level (95% confidence level standard will be 1.96)
p : Probability of realization of the event
m : Margin of error (usually set at 5%)

Considering a probability of 40 and 95% confidence level, the minimum sample size was estimated at about 368 households. Thus, the sample size set in this work would give a good representation. With regard to the daily electricity consumption in each commune, the data were obtained from the National Electricity Company (SNEL).

Data processing: The quantitative data were subjected to one-way analysis of variance (ANOVA) that compares several means and determines whether at least one average is different from the others[28]. If normality or equality of variances is not verified, the data has been transformed into log10. In addition, a *post-hoc* test of Tukey was applied to determine the difference between the means for the result with a significant difference ($p<0.05$)[29,30]. To compare the different communes, the data were submitted to the chi-square test[31]. The qualitative data were submitted to the chi-square test. R 2.15 and Past software were used for statistical analysis. Thematic maps were developed by superimposing on a vectorial map the results of consumer surveys of electrical energy in the residential sector in Lubumbashi after ordination[12].

RESULTS

Figure 1 shows the average daily consumption per household. Households living in downtown neighborhoods

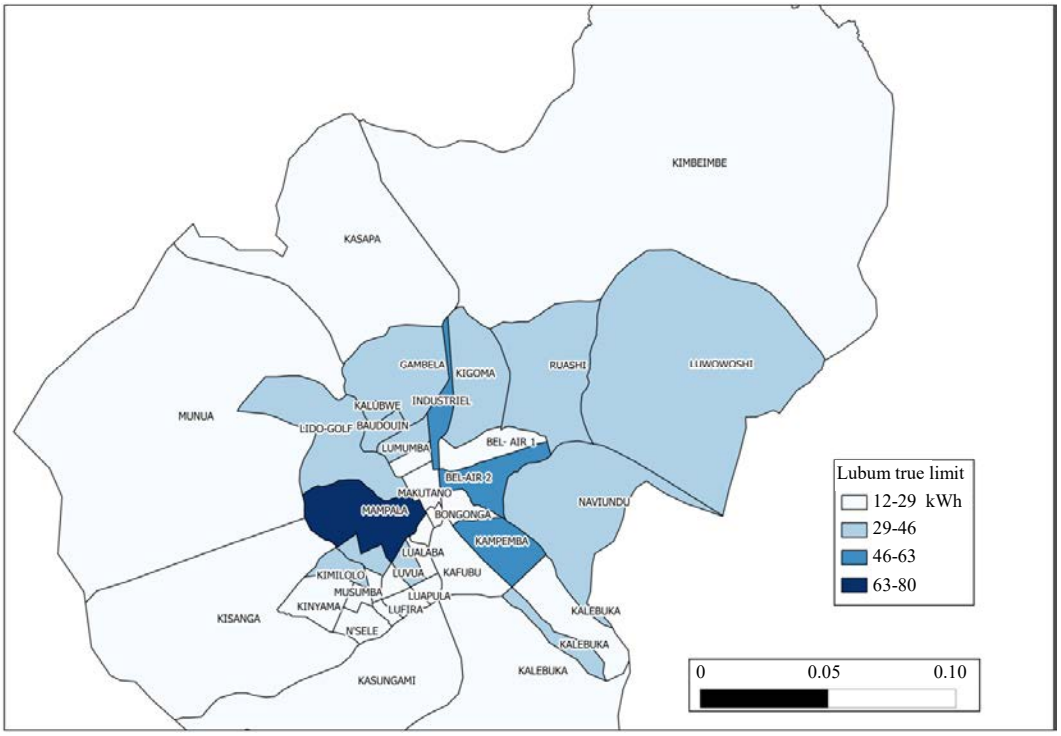

Fig. 1: Daily electricity consumption in different neighborhoods of Lubumbashi
Source: Author's survey

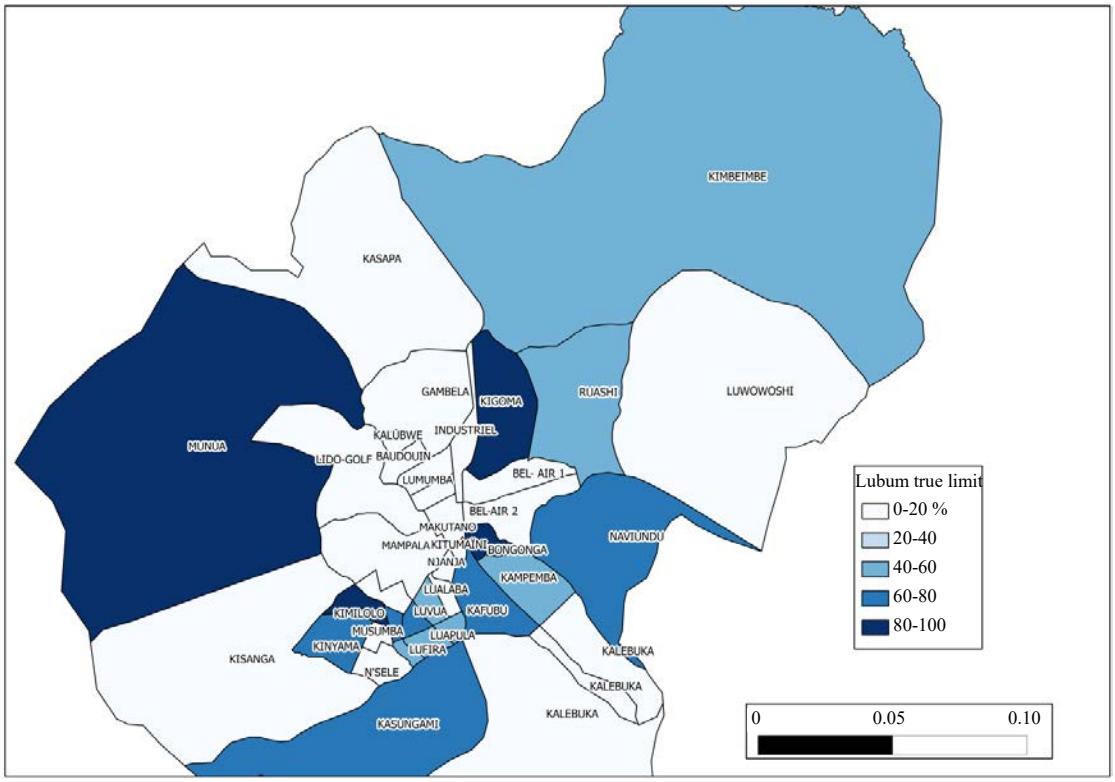

Fig. 2: Fraudulent access rate to the electricity grid
Source: Author's survey

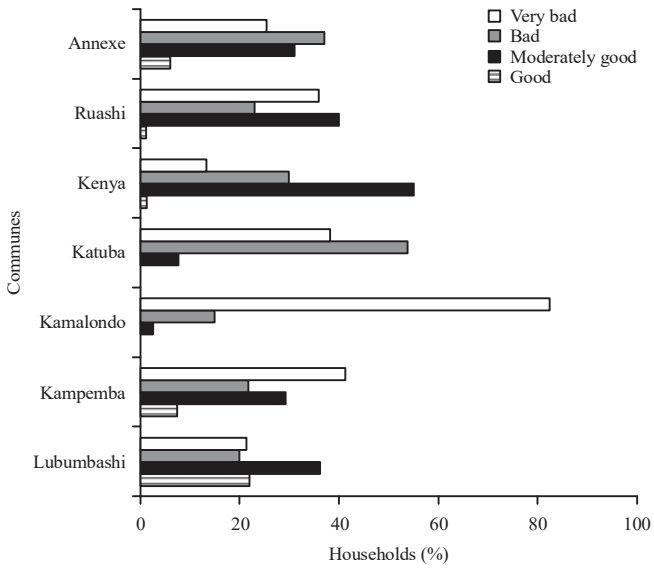

Fig. 3: Percentage of households according to the level of appreciation of the electrical service in all municipalities

with significant economic activity consumed between 63 and 80 kWh per household per day. Central neighborhood households with public administration services and those in outlying areas consumed between 12 and 29 kWh per day per household.

The data Fig. 2 illustrates the cases of illicit connections observed in different districts of Lubumbashi. As a result, the unplanned neighborhoods (Munua, Kigoma, Bongonga and Kimilolo) had the highest illegal connection rate to the network: between 80 and 100%.

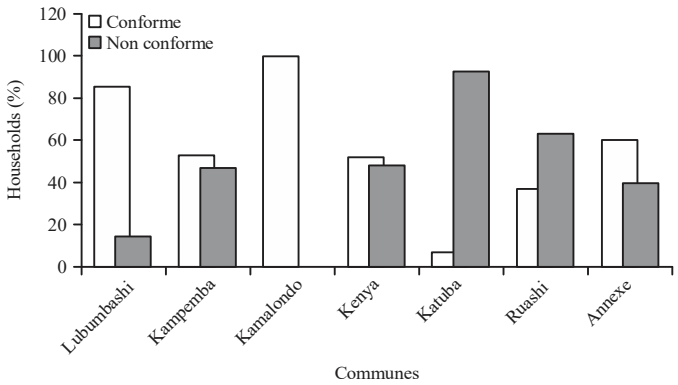

Fig. 4: Conformity of electrical installations in the different municipalities of Lubumbashi

Table 1: Use rate of energy-using appliances in households

	Air-conditioner		Fridge		Bath heater		Welding machine		Mill	
Communes	P (%)	A (%)	P (%)	A (%)	P (%)	A (%)	P (%)	A (%)	P (%)	A (%)
Lubumbashi	2.91	13.37	14.65	1.63	3.49	12.79	1.15	14.76	0.93	15.35
Kampemba	2.21	16.40	9.30	9.30	3.14	15.47	2.79	15.81	0.47	18.14
Kamalondo	0.00	4.65	1.86	2.79	0.00	4.65	0.00	4.65	0.00	4.65
Kenya	0.35	6.63	6.16	0.81	0.23	6.74	2.33	4.65	0.35	6.63
Katuba	0.00	20.93	13.49	7.44	0.00	20.93	5.00	15.93	1.05	19.88
Ruashi	0.58	11.05	7.56	4.07	1.28	10.35	0.70	10.93	0.35	11.28
Annexe	2.44	18.49	12.67	8.26	3.60	17.33	3.26	17.67	1.86	19.07
Total	8.49	91.51	65.70	34.30	11.74	88.26	15.58	84.42	5.00	95.00

P: Presence, A: Absence

The examination of Fig. 3 indicates that the assessment of the quality of electrical service is not similar in all municipalities. In the communes of Kampemba and Kamalondo, the majority, respectively 41.2 and 82% rated the electrical service as very poor.

Disparities were observed in the compliance of electrical installations in households. Households in the municipality Kamalondo had the highest percentage of 100% (Fig. 4).

The results in Table 1 show the level of use of energy-using appliances in the various communes of the city of Lubumbashi. For example, 8.49% of households used air conditioners, 65.7% refrigerators, 15.58% Welding machines and 5% mills.

DISCUSSION

The quality of electrical service is subject to great disparities in the city of Lubumbashi. Some municipalities in the city got benefit from a good report. This was example the municipality of Lubumbashi where 22% of households are interviewed by a good quality electrical service. Municipalities housing unplanned neighborhoods had the highest illegal access rate to the network (80-100%). From results, a disparity between the municipalities regarding the conformity of household electrical installations, the communes Kamalondo and Lubumbashi presented the highest averages, respectively 100 and 80%. Neighborhoods housing the main economic activities of the city had the highest daily electricity consumption compared to neighborhoods housing public administration services and outlying areas. The percentage of good quality of service that benefits the commune of Lubumbashi would be justified by the fact that most of the districts which constitute the commune of Lubumbashi are found[14].

The general trend of the results showed that the majority of Lushois households enjoy a service of average quality. On the other hand, some communes such as Kamalondo and Kampemba mainly benefit from poor quality electrical service. Depending on the quality of the service received the communes can be classified as follows: Lubumbashi> Kampemba>Annexe>Kenya>Ruashi>Katuba>Kamalondo. Some parameters could explained the quality of the service that benefits the city of Lubumbashi. These are mainly: The illegal connection rate, the non-compliance of electrical installations and the use of large energy consumers[25].

Nkosi and Dikgang[32] showed in their work in South Africa that the deterioration of the quality of electrical service was due to the consumption of electricity. This assertion is not

quite tenable in Lubumbashi as part of this study. Because it should be noted that some communes with high daily consumption per household had a high rate of good quality of service and other municipalities with low consumption a low rate of good quality of service. The results of this work revealed that in each commune, there are cases of fraudulent connection to the distribution network that affect the distribution of electricity by overloading the network and thus leading the SNEL to proceed by load shedding. This study also corroborated the claim that the theft of electricity has serious repercussions, on the distribution network and the consumers, it affects the quality of the electricity supply, overloads the production units and causes global losses[3-5,33,34]. This point of view is also shared by other researchers in their surveys in Kibera[35] and in India[34].

However, massive fraud could be attributed to the failure of the state to put in place effective electricity management policies, the refusal to equip new urban areas and the virtual disappearance of the authority of the state as showed[9]. In this context someone stressed that the population of Lubumbashi is involved in a large-scale wild connection to the electricity grid[25]. In addition, in unplanned neighborhoods, on the outskirts of the city, there is rapid urban expansion[11]. Unfortunately, this expansion is not accompanied by installation of new power lines[12]. Given the new economic situation, some households were deprived of power due to the lack of payment of their bills and immediately they connected to the network illegally[12].

The general trend showed that most municipalities have compliant installations. However, the communes of Katuba (92.8%) and Ruashi (63%) have the highest percentage of households whose electrical installations are not compliant. The fact of possessing non-compliant installations explained in certain districts of the city the deterioration of the quality of the electrical service. However, this situation remains relative because the fact of having compliant electrical installations didn't mean to benefit from a good quality electrical service. With regard to the use of energy-consuming appliances, it was revealed that Lush households use them to different degrees. The use varies depending on the type of device and the municipality. This situation would be justified by the different socio-economic levels as observed[14,25]. In the current context of strong urban growth, policies to improve the quality of electrical service must go through the establishment of effective means to fight against the phenomenon of fraudulent connection.

CONCLUSION

From the current study it was tried to identify the causes of the deterioration of electrical service quality in Lubumbashi. Investigations have shown that the fraudulent connections to the electricity grid and the non-compliance of domestic electrical installations are aggravating factors in the deterioration of the quality service.

SIGNIFICANCE STATEMENT

This study revealed that the fraudulent access to the electricity grid and the non-compliance of household electrical installations explain the deterioration of the quality of electrical service in Lubumbashi. It also reveals that the rate of fraudulent access decreases as one move away from the city center. This can be beneficial for utilities and planners by enabling them to take technical and policy measures to reduce theft of electricity. This study will help researchers discover the critical areas of aggravating factors the deterioration of electricity service in Lubumbashi. This has not yet been identified and quantified by previous studies.

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