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Critical analysis of the electricity market in developing country municipality

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Abstract

Developing countries are experiencing significant urban and population growth. This amplifies the crisis of governance of essential public services. This study analyses the electricity market in Lubumbashi, one of the Democratic Republic of Congo (DRC) municipalities. Surveys at different scales are conducted, assessing both access to electricity and the role of actors. 5270 households, 41 policymakers and 100 employees at different scales are interviewed. It has been found that the electricity market is deteriorated by illegal connections to the electricity grid, uncontrolled urban growth, corruption, and poverty. Besides, the quality and cost of electricity decrease with distance from the city centre. Therefore, privatization of the electricity sector would lead to low-cost electricity and high-quality service.

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1. Introduction

While smart grid technologies are transformed from the modern city to a green garden [1], access to suitable electricity is still a bottleneck for several people within the current generation of the 21st century [2–5]. Innovative grid technologies provide the utility power grid with several features to deal with various energy crisis challenges [6]. Therefore, energy security and strategy are developed to ensure the generation mix that can guarantee the optimum

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integration of sustainable energy resources [7]. Nevertheless, urbanization and population growth have reached a breakneck pace, with more than 4 billion people living in urban areas globally [8]. Parallely, more than 1.2 billion people do not have electricity [9], and another 1 billion have access to poor-quality service. African cities are already facing a permanent problem due to the arrival of new populations with no other recourse than to appeal to informal ways to acquire housing and access water and electricity networks [10–12]. For example, in DRC, rapid urbanization creates pockets of high electricity demand. Over 34 million people live in urban areas, or 43% of the population, and this growth is increasing by 4.5% per year.

The weaknesses in the sector's governance, the lack of planning, the insufficient institutional framework, and the lack of government commitment have resulted in one of the world's most significant deficits in access to electricity and substantial geographical disparities [3]. However, electricity is an essential factor that conditions the economic, social, technological, and cultural development of all nations, all peoples, all communities, or individuals taken in isolation. It is one of the sectors considered strategic in the Democratic Republic of Congo (DRC) and whose management is entrusted to the National Electricity Company (SNEL). With 65 million people without electricity in 2016, the DRC is home to the third-largest population without electricity, after India and Ethiopia. With an annual per capita electricity consumption of 94 kWh, half the regional average, the DRC ranks second to last in sub-Saharan Africa. Weaknesses in governance continue to affect the business climate and hamper private sector development and the country's ability to attract investors. Large, complex infrastructure projects are particularly vulnerable to these governance issues. The DRC's power system is also affected by technical and non-technical losses [13]. Technical and non-technical losses represented 36% of total production in 2016 [3].

The DRC lacks information on all aspects of electricity demand, compounding planning difficulties [3,11]. The sheer size of the DRC and accessibility issues make collecting information complicated and expensive. Currently, knowledge of electricity access and governance is still limited. Some city-scale studies report poor electricity quality and increased corruption affecting the control of the electricity sector. In Kinshasa, Mpiana [14] observed a general lack of electrical equipment and national politics to provide electricity in the self-construction areas of the city's periphery. Indeed, the SNEL has not invested for decades. Most of the population bends under the weight of poverty and struggles to develop both formal and informal alternative modes to access the power grid. Muhinduka [5] revealed a form of illegal arrangement between SNEL employees and subscribers or even between the subscribers to have access to electricity, thus weakening the governance of the electricity sector. In Lubumbashi, SNEL faces enormous management difficulties, notably due to urban growth resulting from demographic growth [15]. Uncontrolled urban growth combined with weakened institutions amplifies the deterioration of the quality of the electricity service. Thus, understanding the governance policies of this essential service is fundamental.

In the last 25 years, the city of Lubumbashi has increased its surface area by 215% (219 km²). The town of Lubumbashi is spreading out, but it is also becoming denser. At the same time as this double growth, the electrical infrastructures such as electric cabins and the electricity network are not progressing proportionally. Regarding the rate of access to the electricity network, the city of Lubumbashi has an overall high percentage of electrification. On the other hand, the peripheral parts of the town are mainly less electrified. Despite an access rate of 61.6% at the urban level, the quality of service is getting worse. One of the significant issues in the electricity sector is the lack of decentralization. The provinces do not have the institutional, financial, and technical capacity to provide electricity fully. Coordination between national and local authorities is essential but must go hand in hand with funding allocation [3]. On a city scale, like in Lubumbashi, many stakeholders provide electricity in legal and illegal ways. However, their roles and responsibilities are not clearly defined and reported. Any attempt to improve electricity governance and thus access is to identify legal and illegal stakeholders and analyse the operating system they have established. This study elaborates on a critical analysis of the management of the electricity sector in Lubumbashi. Specifically, we will examine the roles of different stakeholders and the impact of their actions on access to electricity. We will answer the following questions: which public or not stakeholders are involved in the electricity supply in the city of Lubumbashi? How do they operate to provide electricity or access to it?

To answer these questions, we carried out surveys of the populations in all districts of Lubumbashi and the services of SNEL and other stakeholders. Additionally, we conducted multivariate statistical analyses of subscribers' behaviour and electricity governance indicators across communes.

2. Methodology

2.1. Study area

This study was conducted in Lubumbashi, the capital of the province of Haut-Katanga, located in the Southeastern part of the Democratic Republic of Congo (11° 20′-12° 00′ S, 27° 10′-10° 27′ E). The city is divided into seven communes: Lubumbashi, Kenya, Kamalondo, Katuba, Kampemba, Ruashi, and Annexe. Lubumbashi is considered a city that exploded from a new population explosion under the double influence of natural increase and net migration supported by the copper market explosion. Lubumbashi had 413,000 inhabitants in 1973-700,000 in 1988. Recently, the city counted over 2,000,000 inhabitants. The city was supplied with electric power by the thermal power of Union Minière du Haut-Katanga (UMHK). In 1930, connection to the interconnection network of hydroelectric power plants of Lufira was carried out [16]. Therefore, the distribution was ensured by the General Electricity Company (SOGELEC), actually SNEL.

2.2. Surveys and data collection

Two independent surveys were conducted to understand the governance of the electricity sector in Lubumbashi. The first survey included 5270 surveyed in the 26 districts spread in 7 communes of Lubumbashi. Detailed method descriptions can be found in [17]. The aim was to assess household income, electricity quality, electricity access method, distance from the city centre, and used equipment.

The second survey was carried out in 7 service sales centres (CVS) spread in 7 communes of Lubumbashi city, at the SNEL provincial office, and with heads of the electrification committees (34 respondents) at the neighbourhood scale. In addition, semi-structured individual interviews [14,17] were organized with the head of CVS of each commune, employees, and daily labourers (both formal and informal) (57 respondents). In each CVS, the interviews with the employees were carried out in an isolated manner to avoid the mutual influence of the opinions. Other labourers, including convenience stores, met in the various streets of the city during our visit and were also interviewed (43 respondents).

2.3. Statistics

A principal component analysis was performed to characterize the distribution patterns of household income, electricity quality, electricity access method, distance from the city centre, used equipment, and SNEL infrastructures across the district in Lubumbashi. In addition, to compare mean income, electricity cost, and electricity cuts, a One-way ANOVA was performed. All statistical analyses were performed using R software, version 4.0.1 [18].

3. Results

3.1. Subscribers' behaviour and electricity governance indicators across communes

The two first dimensions of the principal component analysis (PCA) explained 31.1% of the variance of the dataset, as presented in Fig. 1. Subscribers' behaviour varies from one district to another. Some communities show specific behaviour and characteristics, while others gather all different subscribers' behaviour and electricity governance indicators. Besides, the Annexe district is characterized by its location, distance from the city centre, and high weekly and daily electricity cuts, like the Ruashi district. Long-distance from the city centre and electricity cuts negatively correlate with safety measures, SNEL offices, and electricity meters. Kamalondo district is markedly distinct from other communities due to the strong presence of electricity meters, SNEL offices, maintenance programs, and informal connections to the power grid. Kampemba and Lubumbashi districts gather all categories of subscribers and electricity governance indicators. Most of the population in Lubumbashi district has the highest monthly income, uses formal electricity access procedures, receives a monthly bill, and pays the most increased electricity cost.

Similarly, the Kenya district shows high monthly electricity costs. Late payment penalties primarily found in the Kamalondo district and other households from Lubumbashi and Kampemba districts are positively correlated with a high frequency of use of generators. However, the late payment penalty is negatively correlated with a high

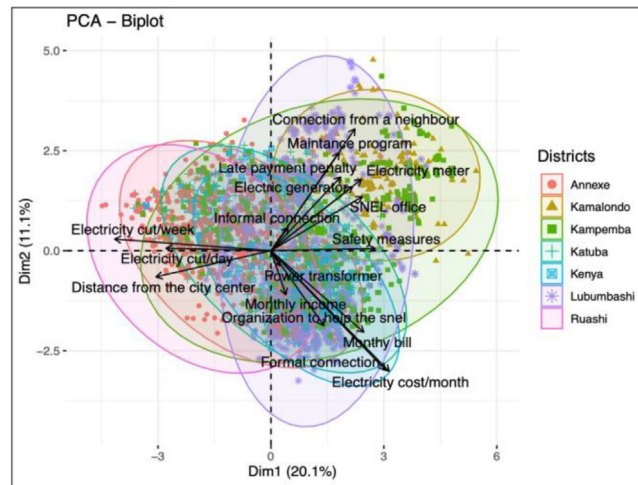


Fig. 1. Principal component analysis (PCA) for characterizing subscribers’ behaviour and electricity governance indicators across districts.

frequency of power transformers, high monthly income, and local organizations that help the SNEL. Furthermore, high monthly income in the Lubumbashi district strongly correlates with local organizations that support the SNEL.

Lubumbashi district has the highest monthly income, followed by Kamalondo and Annexe, respectively, while Kenya district has the lowest, as shown in Fig. 2a. The highest number of daily hours of electricity cuts is observed in the Ruashi district, followed by the Annexe district, while the lowest is in the Katuba district, as presented in Fig. 2b. Lubumbashi district has the highest monthly electricity cost with the highest monthly income, followed by Kenya. Annexe, Kamalondo, and Ruashi communes have the lowest monthly electricity cost. Kampemba and Katuba districts show similar monthly electricity costs, as described in Fig. 2c. The highest number of electricity cuts per week is observed in Ruashi and Annexe districts, while Kamalondo, Lubumbashi, and Kenya districts have the lowest, as detailed in Fig. 2d.

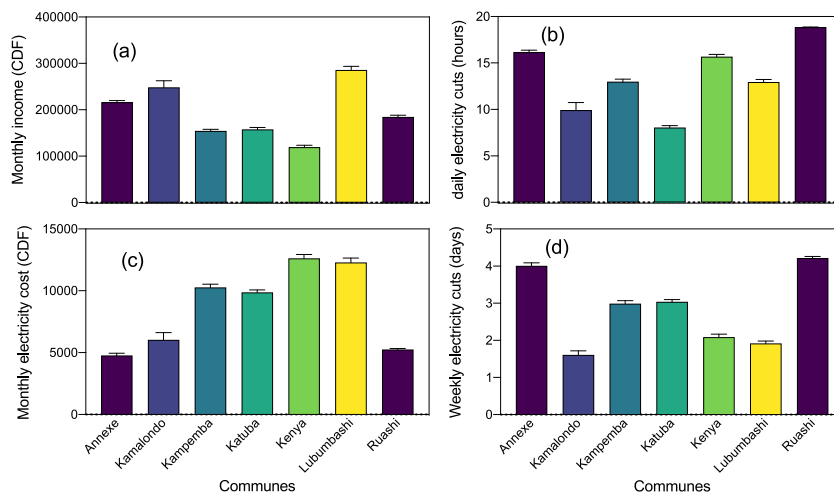


Fig. 2. Comparison of monthly income, electricity cost and supply quality in different districts of Lubumbashi.

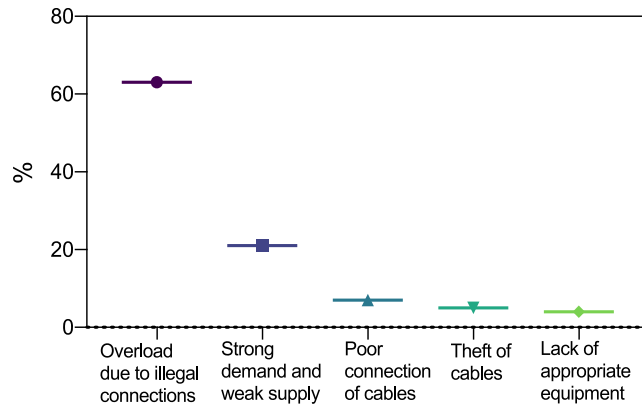


Fig. 3. Problems affecting the electricity supply quality as suggested by subscribers, daily labourers, and SNEL agents (n = 136).

3.2. Identified factors affecting the quality of electricity supply

Subscribers, daily labourers, and SNEL agents identified overload due to illegal connections as the primary factor affecting the quality of the electricity supply in Lubumbashi, as presented in Fig. 3. Following the excess, the increasing demand for electricity without a subsequent increase in the offer was identified as a second major factor affecting the quality of electricity supply. In addition, poor connections of eclectic cables, theft of lines, and lack of appropriate equipment were identified among the factors affecting the quality of the electricity supply.

3.3. Stakeholders in the governance of the electricity sector

The SNEL, a public company, manages the electricity sector. The provincial SNEL office in Lubumbashi works closely with CVS and electrification committees spread across different city districts, as shown in Fig. 4. CVS provides electric contract and service to subscribers and work with daily labourers to ensure the daily quality of the service and fix technical issues. Electrification committees are groups of inhabitants of different districts, mainly in new neighbours where SNEL offices and services are scarce. They contribute to buying electrical equipment,

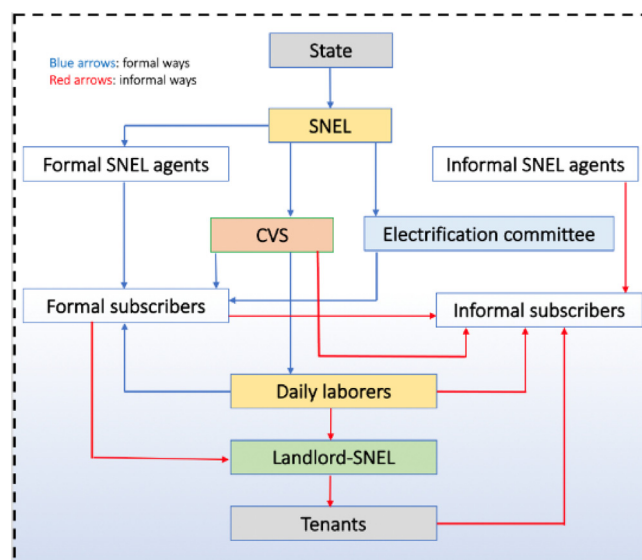


Fig. 4. Regulatory model and stakeholders involved in electricity supply in Lubumbashi.

allowing them to connect to the electricity network of SNEL in legal collaboration with the latter. The informal electric service usually starts at the CVS scale, where subscribers pay illegally and directly the monthly cost to certain corrupt officials. Similar arrangements occur between daily labourers or formal subscribers and informal subscribers. In most cases, a landlord with legal access to the electric service can mainly become an informal distributor of the electricity to their tenant. This is due to the lack of electricity metering infrastructures.

4. Discussion

4.1. Lack of decentralization of actions and urban growth affect the governance of the electricity sector

The central government financed the local production of electricity and managed the SNEL. The SNEL faces significant financial difficulties leading to poor quality of electricity supply. This has also been revealed by Edomah et al. [19] in Nigeria. The SNEL at the local level cannot carry out the necessary actions to improve the quality of the service provided to the population [17]. The SNEL at the province level is not autonomous and has to transfer its revenue to the central government, thus relying on the central government's retrocession. Like most cities in DRC, Lubumbashi does not have the institutional, financial, and technical capacity to fully assume the role of negotiating contracts. Therefore, to provide electricity must resort to the central government. A similar situation was observed in China, where the electricity sector has many consequences. Transmission and distribution infrastructures over most of the country are owned by one vast company. Economic competition based on cost does not exist; dispatch is planned and politicized.

Furthermore, tariffs bear little relation to the balance between supply and demand [20,21]. In other countries, such as the Ivory Coast, private involvement in the electricity sector does not only involve the area of production [22]. Instead, the central government conceded responsibility for operating the entire industry to a private company. This model has responded positively even during the period of political crisis. This imposing rise in power responds to growing demand and cannot be done without the involvement of the private sector [19].

The current electricity service regulation model does not consider the densification and spread of the city [15]. Yet, these two aspects of urban growth have drastic consequences for the efficiency of the mode of governance. In the context in which urban development is not considered, essential urban services are affected, which generates financial difficulties when the vulnerability of the electric infrastructures is coupled with their obsolescence. The deterioration of the quality of electricity due to the dilapidated infrastructure aggravates the economic challenges of SNEL. Although the urban population is growing, urban policies aimed at providing electricity to households do not consider this component. The old neighbourhoods (most) are equipped with electric infrastructures, and the new peripheral communes are the reception centres of all the other populations that flood the city. This choice to live in the old neighbourhoods is reinforced by the fact that in most cases of rural exodus, the need of the new city dweller is to live in a house, although small but served with water and electricity. This situation makes the old (central) neighbourhoods more and more densified [17]. The uncontrolled development of the self-building areas that have been grafted on the planned cities of colonial origin, coupled with the increasing demands for housing and dissatisfaction by the public authorities, leads to a proliferation of the self-building areas located at the periphery both spatially and socially [9,17].

4.2. Governance of electricity sector at the city scale: roles of stakeholders

The provincial SNEL office in Lubumbashi city works closely with CVS and electrification committees spread across different city districts (Fig. 4). Katcho [23] noted that the electrification committees were born of state failure of SNEL and the government in their attempt to supply electricity. The emergence of electricity committees and their support for the SNEL have been observed in other cities of the Democratic Republic of Congo, such as Bukavu [5]. The activities of the electrification committees are limited to financing the engineering work of building cabins according to the standards established by SNEL, and some committees manage to take charge of all the electrical equipment (transformer, circuit breaker). The population represented by the committees incur all expenses. Once the electrical cabin is installed, and in service, the SNEL does what is called "compensation", i.e., the consumption bills of customers, committee members or even those who have contributed are compensated by the amount that each household has given and this until the day when the entire sum will be estimated reimbursed. Currently, the cabin has become the exclusive property of SNEL. However, the electrification committees do not have precise

legal statutes, the management of certain committees is criticized, and the interference of SNEL in the activities of the committees, especially in terms of the management of donations received from third parties, are the main difficulties encountered by electrification committees

In addition to CVSSs, customers, and electrification committees, actors involved in the electricity sector include street chiefs, neighbourhood chiefs, and even the National Intelligence Agency (ANR). Street and neighbourhood leaders are administrative authorities that guarantee the security of electrical infrastructure beyond their fundamental mission. They join forces with the electrification committees to limit the theft of electrical cables and involve SNEL technicians in case of disruption of the electricity network. However, the electricity supply is predominantly characterized by informal procedures. At their level, street and neighbourhood leaders have established an illicit arrangement allowing informal subscribers to connect to the electricity grid.

The precarious working conditions lead to a functional mutation of the employees operating in the CVS. These employees use a form of “informal business”. Apart from informal arrangements with subscribers, these actors deliberately cut off electricity and force outages to encourage subscribers to use the technical workforce. When these technicians (daily labourers or permanent agents) intervene, the inhabitants of the district concerned must make contributions of money to pay the double agent (who creates the breakdowns and interferes with troubleshooting). Customers are not allowed to claim compensation in case of frequent electricity cuts. These are only theoretical if any terms and conditions are agreed upon in subscription contracts. These practices became incessant and thus constituted a source of income for agents operating illegally. Daily labourers, formal, informal, and permanent employees, have become unlawful electricity marketers. They conspire with the electrification committees or the subscriber to operate illegally. The motivation of these agents is mainly due to the absence of a regular and satisfactory salary. All these irregularities in the management of the electricity service constitute a shortfall for the company (SNEL), which is already financially weakened.

Another “informal business” form is seen in the old, densified neighbourhoods. Indeed, in collaboration with informal labourers (so-called operating on the orders of the CVS), some traders connected to the electricity grid whose voltage drop is permanent proceed to targeted power cuts. Informal labourers, for example, deprive other households of electricity by favouring the only trader who pays them a bribe to run his business normally. For others, such as owners of nightclubs and cinemas, the intentions are different, and they plot with informal labourers to deprive the electricity to their competitors and win the customer.

The follow-up in governance at this level is difficult because the informal way is generalized in all actions at the neighbourhood level. Subscribers, who are also one of the leading players, are the most corrupt. They prefer the informal way because it is cheaper and faster than the formal way requiring lengthy procedures, yet the result is the same. This culture, which has now become a standard procedure, highlights the weakness of the government policy at the grassroots level (at the neighbourhood level). The common practice of access to electricity is now sloppy in the districts of Lubumbashi [13]. Anarchy in the governance of the electricity sector is observed at all levels at the neighbourhood level. In the neighbourhoods of self-construction, SNEL agents’ visits are far from frequent. In this situation, the agents of the ANR have also become controllers of the electricity network. They set up arrangements with “protected” subscribers who can no longer pay SNEL’s bill. The protected subscriber is thus obliged to pay the ANR agent who protects him; nevertheless, he spends the third or half of the bill he owes to SNEL.

4.3. Subscriber’s behaviour differs between communes

The old neighbourhoods (neighbourhoods forming the core of the city with planned and dense buildings) concentrate most of the electrical infrastructures in Lubumbashi, although obsolete in some cases. Older neighbourhoods are becoming denser because they offer people an advantage in terms of electricity access. In the high-density building, the distance of the household compared to the nearest electric pole is reduced, which presents a considerable advantage if it is necessary to connect to the power grid.

Most plots are home to several households paying the landlord’s outstanding bill. The conditions in these neighbourhoods are such that: the landlord receives the bill from SNEL and contributes to the tenant households to pay this bill. This approach reduces the cost of access to electricity for these households [13,15,17]. In addition, these renter households, not officially recognized by SNEL, are not required to follow the normative electricity access rules. Under these conditions, even low-income families can access the electricity grid. In addition, these old, planned neighbourhoods (including Kamalondo, Kenya, and partially Kampemba communes) are becoming

denser each year. The consequences of this demographic flow are worrying from the point of view of access to electricity.

However, the problems observed in spontaneous neighbourhoods (mostly Annexe commune) are different. Scattered buildings do not allow easy access to electricity, especially for low-income households. The Annexe commune is characterized by its location, a long distance from the city centre, and high weekly and daily electricity cuts, similar to the Ruashi district. A low-income household may not access the electricity grid in these low-density peripheral neighbourhoods. Yet, with the same (low) income level, a home in a formerly planned and dense neighbourhood may be easily connected to the grid. SNEL's actions in these neighbourhoods are minimal. Indeed, electric infrastructures are rare. Only high-income households could access the electricity grid by paying for their transformers or installing the poles and electrical cables needed to connect to the grid. In these neighbourhoods, access to electricity could be used to estimate the level of household income. Nowadays, actions related to the electrification of these neighbourhoods have benefited the support of politicians (during electoral campaigns), the governor (donations), NGOs, or the community itself. SNEL's inaction and the need for access to electricity led to the creation of local electrification committees at the neighbourhood level. Other households have established various sources of electricity, including photovoltaic energy as an individual solution and mini-diesel networks as a collective solution.

Some strengthened governance measures are the fight against corruption through public education, information, and the denunciation of abuses. Public information campaigns have yielded significantly productive results in several battles against bad practices such as electricity theft and corruption [24]. Indeed, these information campaigns have helped educate and promote positive behaviours among the population and those in power. Several authors suggest recourse to the media for this purpose, including regular media interventions, public service television announcements, web pages, religious sermons, and information placed directly on electricity bills for the consumer [24,25]. Indeed, the media can control corruption by informing decision-makers and public authorities, raising public awareness of corruption, its causes, consequences, and possible remedies, exposing corrupt officials and instigating investigations by official bodies [25]. Besides, Onat [26] proposes three strategies to assess the public information: (i) raise public awareness about the economic dimension of the illegal use of electricity, (ii) communicate the social damage of the illegal use of electricity and (iii) communicate the relationship between illegal use of electricity and religious and moral values. Furthermore, the integration of sustainable energy resources can assist in mitigating the load shedding programme that the entire country is currently facing [27].

5. Conclusion

The lack of decentralization is one of the significant factors affecting the governance of the electricity sector and electricity supply. Since SNEL revenues are transferred to the central government at the province scale, relying on retrocessions that are usually rare to develop the electricity sector and improve the electricity supply is not comfortable. Moreover, like most cities in DRC, Lubumbashi does not have the institutional, financial, and technical capacity to fully assume the role of negotiating contracts. Therefore, to provide electricity resorts to the central government. We showed that governance of the electricity sector in Lubumbashi is weakened by informal arrangements at different levels leading to illegal connections to the electricity grid. This situation creates overload and poor-quality electricity supply. Quality of electricity supply and electricity cost decrease with increasing distance from the city centre. SNEL offices and infrastructures are scarce in self-building areas. Peripheral neighbourhoods, the product of uncontrolled urban sprawl, constitute a significant challenge for weak SNEL.

The access to the electricity grid of these spontaneous neighbourhoods is challenging due to their distance from the city centre, making widening the electrical network too expensive for the SNEL. Moreover, high-density buildings mainly characterize the inner-city; households are more easily connected to the electricity grid than households from new self-building areas. It is, therefore, necessary to propose solutions to improve the governance of the electricity sector. These solutions should include privatization of the electricity sector, creating concurrence, low-price electricity, and high-quality service. In addition, urban and population growth dynamics must be considered to adapt electricity production to demand. Finally, SNEL should implement strategies to stop shortfalls caused by electricity theft, lump-sum billing, and corruption. Furthermore, integrating sustainable energy resources should guarantee an affordable, clean, secure power network.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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