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SOCIO-TECHNICAL DYSFUNCTIONS AND THERAPY FOR THE SUSTAINABILITY OF PUBLIC LIGHTING BY AN OFF-GRID SYSTEM IN BOHICON

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Abstract
The provision of essential services is one of the missions that focus public service investments. But their durability is often questioned for many reasons. In order to approach the probable causes of this weakness in public action, the present study was able to observe the equipment of the off-grid public lighting system in the city of Bohicon and to detect the related shortcomings. The shortcomings observed are of a technical, technological, institutional and social nature. Permanent technological and institutional innovation therefore appears to be a source of renewed virtue in the provision of various public services.

1. Introduction

Due to its position as a crossroads connecting the north and the south of Benin on the one hand as well as the neighboring countries of Nigeria and Togo and all the towns in the center of the country on the other hand, Bohicon has experienced increasing urban development for several years and this according to the aspirations of the ruling class as noted by Criqui [1, p. 12] for who, " *planning has largely lost its spatial dimension in favor of a political approach*". The immediate consequence of such a choice of paradigm is the accentuation of the subequipment in essential infrastructure so that all sectors of town planning are in a situation of extreme emergency [2]. Faced with this deficit balance of citizens' aspiration to better community life, thehe political leaders invest mainly in the construction of infrastructure, development and public equipment, to the point where political action is sometimes confused with this type of action [3]. In this permanent race to increase the infrastructural resource, the sustainability of investments is relegated. Thus, the absence or failure

of management and maintenance mechanisms for urban infrastructure and equipment favors their early failure, undermining the efforts made and forcing a perpetual restart of actions already undertaken.

At the same time as these concerns, the disproportion between the resources that can be mobilized and the needs for essential services, as well as the increasingly considerable financial costs generated by the search for financing, make it essential to optimize the lifespan of urban infrastructure and equipment. To approach this logic, this study was based on the public service of public lighting in this medium-sized city in central Benin where innovative solutions have recently been developed for the provision of this essential service in areas not covered and where, the connection to traditional systems presented difficulties which could only lead to postponing the principle of equality of all before the public service. But the failure of these policy changes may become an opportunity if the right lessons are learned from the reasons that supported the anomalies. This therefore constitutes the main object of this reflection.

2. Methodological approach

The objective of this reflection is to identify the problems linked to the use of decentralized solutions for the provision of the public service of public lighting in the city of Bohicon. Specifically, it addresses the various technologies developed and identifies the technical and social problems related to solar photovoltaic systems. Based on this apprehension, the study then considered solutions to make the investments made sustainable. To this end, the process consisted of three stages. Initially, the documentary review made it possible to clear up the various facets of the question and identify the additional information needs necessary for the analyzes. The field surveys then helped fill the data gap through a direct observation campaign of solar photovoltaic public lighting systems. The observations were made day and night and were spread over five days and resulted in the establishment of the inventory of installations based on a typology of failures. Interviews with local residents made it possible to detect the plausible causes of the limits of sustainability linked to human actions. In a third phase, the study dwelled on the data collected in order to carry out technical, social and security analyzes and therefore propose possible solutions to ensure the continuity of the supply of public lighting involving decentralized solutions.

3. Results and discussion

3.1. Geographic and institutional framework

The Commune of Bohicon is located in the center of Benin and is an extension of the geographical territory of what remains today of the former kingdom of Abomey. Extending over an area of 139 km², it is home to a population of over 100,000 inhabitants according to the projections of the 2013 General Population and Housing Census. It forms with its neighbour Abomey, "an urban agglomeration which is gradually structured" [4, p. 109].

Administratively, 10 districts make up the territory of this Municipality which includes both a dense urban environment of 17 city districts and a rural part spread over 33 villages and 207 localities.

Law 97-029 of January 15, 1999 on the organization of Municipalities in the Republic of Benin defines the institutional framework for the management of towns and therefore for the provision of essential services. The requirements of this provision determine, in the field of infrastructure, three types of powers:

i. the initiation of operations for the development of infrastructures and equipment which are part of their heritage,
ii. management and maintenance of infrastructure and municipal equipment and,
iii. construction, maintenance and management of municipal infrastructure and equipment (urban roads and their sanitation networks, bus stations, lighting networks, car parks, etc.).

The crossing of these provisions is the foundation offering to the decentralized communities, the right and the effective capacity to regulate and manage under their responsibility and for the benefit of their populations, the local public affairs. It is therefore in this capacity that the Municipality of Bohicon is responsible for offering the public service of public lighting.

3.2. Public lighting technologies

The lighting of the tracks is achieved by lampposts of determined height, located at the edge of the roadways or in the central platform (TPC), in a certain geometry and at regular intervals. This system is composed of:

i. The source of light;
ii. The post or mast;
iii. The concrete fixing base.

In the case of conventional public lighting, the electric light source is powered by connection to a distributed electric network, while in the case of solar, the electric energy is provided by a photovoltaic system which converts the sun's rays into electricity. The latter case can be common or decentralized. The use of conventional energy is limited by several economic and technical constraints such as the remoteness of localities from the existing network and the very high cost of their connection.

Faced with such difficulties, Lapp [5, p. 8] proposes the promotion of decentralized energy to abolish the border between supply and demand.

Decentralized or isolated solutions are defined according to Kanchev [6, p. 25]by "the production of electrical energy using small power installations connected to low voltage networks, unlike centralized high-power production, connected to the transmission network". The World Bank estimates nearly 420 million, the number of people who use this source for lighting and other energy services around the world [7, p. 15].

The solutions are divided into two (02) types of systems: domestic systems and mini-grids [8, p. 12]. Their production comes from primary sources of fossil and renewable energies. The constraints of sustainable development encourage recourse to the later category at the expense of fossil sources. In this category and because of the permanence of the sun, solar energy seems to be a considerable option. The Renewable Energy Development Center of Algeria [9, p. 30], the defines as "energy recovered and transformed directly into electricity from sunlight by photovoltaic panels". The table below compares the strengths and weaknesses of this technology.

Table 1 : Advantages and disadvantages of solar generators

Solution	Benefits	Disadvantages
Solar generators	Decentralized generation Limited maintenance Can support a mini distribution network Low operating load Does not require a monthly fee	High installation cost The reliability of equipment components is limited Secure a large space for the installation of the solar field Production fluctuates with the vagaries of the weather

Source: [10]

By analyzing the drawbacks of this technology, it emerges from the economic, technological and technical constraints for the development of this type of solution. Therefore, great care is essential when sizing installations as well as choosing equipment. Since sunlight is the key element in the performance of this solution, it requires special consideration. However, according to ASECNA [11], the measurements of this constancy give for the city of Bohicon, an average value of 5.07 kWh / m2 / D with an almost similar distribution over all the months of the year. This rate therefore ensures continuity of solar radiation used as a primary energy source.

3.3. Design of public lighting systems

The solar photovoltaic public lighting system is broken down into nine (09) components:

- The support or post and its fixing elements
- The concrete fixing base.
- The luminaire
- The solar panel
- Battery
- The charge regulator
- The twilight or time switch
- Connection cables,
- The elements of the earthing system.

The sizing of the support, its fixing elements and the concrete fixing base is a matter of civil engineering techniques. For the other elements, their choice results from photometric, energy and electrical calculations.

In order to optimize the energy produced by these installations, the choice of high energy efficiency luminaires is necessary. And it is in line with this logic that LED lamps are used more and more. At the same time, the sizing of the batteries and other electronic components depends on the performance (such as rated capacity, 20 ° life, deep discharge, number of days of autonomy) desired for the system.

The table below summarizes the characteristics of the different equipment for each component of a streetlight.

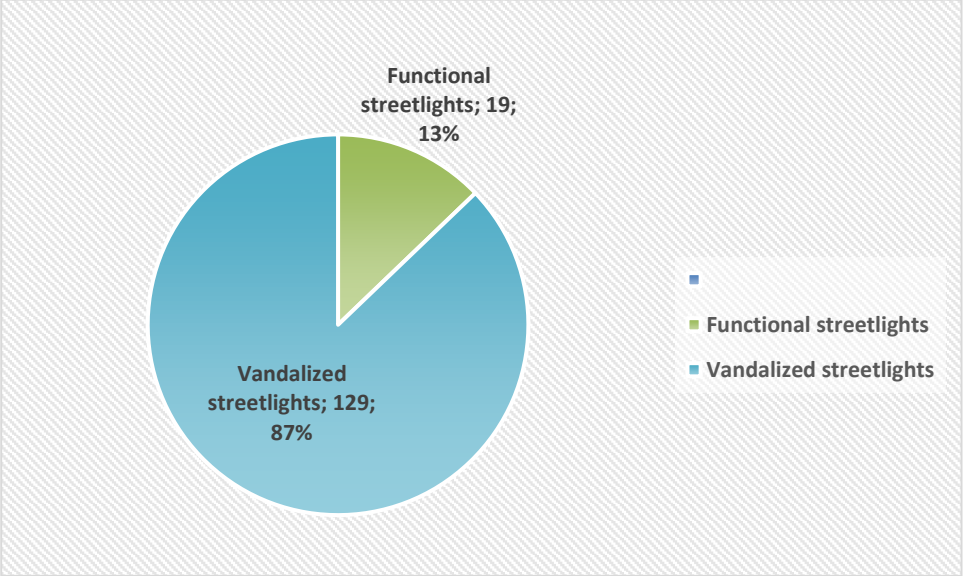
Table 2: Characteristics of the elements composing a floor lamp

Designation	Technical Summary	Quantity
Solar panel	120 Wc, high efficiency, monocrystalline, connection box IP67, 25 years' service, 10 years warranty. Voc=21,6V; Isc=8,08A; Vmp=17,0V; Imp=7,06A	02
LED	80W D24V. 120lm/W, IP67 IK07, Operating temperature: -40 to 55°C; 50,000 hours of operation and 5 years of warranty	01
Controller	24V/15A, IP68; intelligent module with integrated electrical protection	01
Batteries	12V/150AH; GEL battery, no maintenance, 45 kg	02
Battery cage	Hot-dip galvanized metal with paint treatment	02
lighting column	9m high/light point: 8m, sheet thickness: 4mm; hot galavanise.	01

Source: [12, p. 12]

3.4. Problems with off-grid lighting

In order to diagnose the decentralized network of public lighting, the observation focused on 148 lampposts, 19 of which are still functioning. This gives a running rate of about 12% as shown in the table below.



Board 1: Comparison of functional streetlights / vandalized streetlights

The observation of a low rate of Streetlights illustrates a failure in the sustainability of this public service, the installations of which were put in place from 2015 and remain under warranty as summarized in the table below.

Table 3: Service time / Guarantee offered

Equipment	Service time	Guarantee offered
Solar panels	25 years	10 years
LED lights	50,000 hours of operation	5 years

Drums	500 cycles at 100%; 700 cycles at 75% and 1200 cycles greater than 50% with a 3-day autonomy	Over 12 years

Source: [12]

The equipment being under warranty and non-functional pose the problem of ignorance of the rights relating thereto as underlined Lighting Africa [13], for who "End users often don't know they are entitled to warranty and service." This ignorance of the supplier's duties limits the demand for such services by network managers. Moreover, in view of the types of degradation to which the installations are subjected, it is to be feared that the application of the guarantees will be possible. The following table describes the different types of destruction of solar street lights.

Table 4 : Lamp post vandalism mechanism

Method of destruction	Description	Frequency
Traffic accident	The mast put on the ground thanks to the shocks, the solar panels, the batteries and the lights are then stolen	9.30%
Flight after a section of the mast	The mast is cut with a saw and the solar panels, the batteries, the lights are then taken away and part of the mast cut into a piece of iron is then taken away	27.91%
Flight without destruction of the mast	masts are left standing and vandalized (solar panels, bacteria and light fixtures carried	62.79%
Total		100%

Reading the results of this table highlights three types of degradation of photovoltaic solar street lights. In a first category, the operating mode of the destruction by section of the lampposts consists in taking advantage of the drop in traffic on the main roads at night in order to immobilize a moving truck, the hum of which conceals the noise of the saw on the pole. The following photo shows a sectioned lamppost.

Figure 1: Sectioned and vandalized lamppost

The technique of destruction by severing the masts requiring significant logistical means (running truck, saw, etc.), generating noise when the mast falls and being able to arouse suspicion when a moving truck is immobilized near it a lamppost, vandalism practices have evolved. Thus, the posts are ransacked while being in place as shown in the following photo.

Figure 2: Lamppost vandalized without prior destruction of the pole

The innovation in evil engineering for this mode of operation therefore consists of climbing at night, the poles in working order and dismantling each of the components of the electrical system, which are solar panels, batteries, lights and controls. This approach, which represents more than 60% of the destruction of lampposts, has become widespread over time.

A third form of destruction is caused by traffic accidents during which mechanical shocks destabilize the inertia of the masts and cause them to collapse. Therefore, the theft of ground equipment becomes very easy. The following photo illustrates a floor lamp of this category.

Figure 3: Theft after destruction of the mast by an accident

In general, acts of vandalism of streetlights mainly concern batteries, solar panels and lighting. However, the observations also show isolated cases of theft by pieces, of the candelabra on the ground. In total, the destruction of nine out of ten lampposts is due to premeditated theft.

By observing the positioning of the installations, it emerges that almost all the non-vandalized lampposts are concentrated in high-traffic areas such as the bus park and the jumbo car park, while the others are located either in front of residences or in front of hotels or in non-conglomerated intervals. This conclusion therefore shows that the isolation of streetlights is a determining factor in their destruction. In addition, the systems having been installed by the Government which has not yet carried out the transfer to the benefit of the Municipality, the lampposts do not benefit from any maintenance plan, thus causing a gradual deterioration in the performance of the installations.

All in all, the failures of the systems for the provision of decentralized public lighting systems are of a technical and social nature. From a technical standpoint, the failure to take into account the possibility of theft of various electrical equipment (solar panels, batteries and lights) during the design of the system did not allow the development of mechanisms likely to limit them. Likewise, the decentralized supply of electrical energy and therefore the non-connection of isolated streetlights explains the ease with which the destruction of public goods is carried out. The absence of a maintenance plan for the components of each system also does not favour the implementation of routine and periodic maintenance operations.

This failure is aggravated by the institutional weaknesses of the project set-up. Thus, since the mechanisms for transferring responsibilities between the Government (having carried out the installations) and the Municipality (responsible for operating and maintaining them) have not been established, no responsibility for maintenance operations can be guaranteed to the current stage.

In addition, the installation project having been led by the Government, the involvement of local actors in its management is limited. As a result, the monitoring of equipment by the communities remains uncertain. Likewise, the results of the police and judicial investigations which followed the findings of destruction of the public good remain mixed and therefore do not destabilize the networks of vandalism actors.

3.5. For off-grid lighting sustainability

In view of the diagnosis from auscultation of decentralized public lighting supply systems, technical and organizational innovations are inevitable to prescribe any effective therapy. Based on the observation made by [14, p. 4] according to which, "in most current projects there is no definition a priori of the sustainability of an urban infrastructure, for example through the application of a grid of sustainable criteria, nor an" optimum "Sustainability to be achieved", achieving this prerequisite is the starting point for any sustainable solution.

As a result, the establishment of a maintenance and upkeep plan involving clearly verifiable results makes it possible to make the actors responsible and to offer them a guide for the actions to be carried out. Such a common thread detailing the roles and responsibilities of each actor requires a permanent assessment and constant involvement of the local populations benefiting from the provision of the public service. Likewise, based on the fact that acts of sabotage mainly focus on batteries, lights and photovoltaic solar panels, the indelible and irreversible marking of this equipment could limit the transactions that follow the thefts. These stamps produced at the factory during manufacture must be easily identifiable in order to be reported to the authorities in the event of discovery in inappropriate places. The discreet integration of geo-referenced chips or sensors during the manufacture of equipment could also constitute an additional source for security when the identification of stolen parts could be facilitated.

Finally, recourse to solutions of the "all in one" type incorporating the various components of the system in a single, interdependent element is likely to limit the hidden markets for the sale of spare parts from solar street lights.

Conclusion

The sustainability of essential services is a citizen's right which requires numerous technical, technological, institutional and social investments. But in many cases, the public authorities develop the infrastructure without associating with it the mechanisms capable of perpetuating the services offered to the citizens. In the city of Bohicon in central Benin, technological innovation has made it possible to develop the supply of off-grid public lighting thanks to solar photovoltaic technology. But the gains from this investment did not last over time. Numerous acts of vandalism have destroyed the lampposts thus installed while they remain under warranty. Faced with this extraordinary challenge, tackling this problem becomes essential, because the challenge is not to provide ready-made solutions, but to encourage the creation of constant emulation. It is therefore in such a dynamic that this study has explored the contours of this form of deviation from the normal, which is extremely harmful to the common interest, and has considered possible technical and societal solutions capable of reversing the negative dynamic established in the engineering of evil.

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