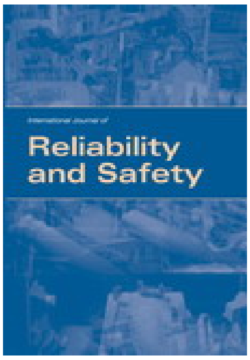

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Post COVID-19 electrical load shedding on Cameroon's northern interconnected grid: causes, safety impact and solution proposals

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Post COVID-19 electrical load shedding on Cameroon's northern interconnected grid: causes, safety impact and solution proposals

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Abstract: This paper, after assessing and ranking power shortage causes in Cameroon's northern Interconnected Grid, summarises the impact of power shortage on poor households and district hospitals. The results showed a drop of 40% of the supplied energy and the fluctuations of demand continued across the COVID-19 period till July in 2021 after lockdown, thus a low influence of the pandemic. The results also revealed a low influence of temperature and precipitations in the energy crisis. Instead, it was found that the most important factor that led to power shortage is electricity production cost which is higher than market price. Out of seven hypotheses tested by the structural model developed, five were significantly supported and two were rejected. The hypothesis testing showed that electrical fire safety and patient care in hospitals are both positively significantly affected by load shedding, hospital management and user's safety commitment and knowledge. Also, the results showed that neither safety knowledge nor safety impact is affected by demographic and socioeconomic variables. Using these results, a series of recommendations were given to energy practitioners and grid managers.

Keywords: post COVID-19; load shedding; safety impact; structural equation modelling; Cameroon northern interconnected grid.

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1 Introduction and background

After COVID-19 hit the world and changed people's lifestyle in the first quarter of year 2020, most countries faced huge economic recession and challenges. People in many parts of the world lacked access to the most basic energy services, including electricity for refrigeration, operation of water supply pumps and medical services (Brosemer et al., 2020). In Africa especially, countries faced the crisis while having to deal with existing issues and without robust contingency plans, the laws of electricity demand-supply have been modified.

In Cameroon, for example, the northern interconnected electrical grid has been facing since October 2020, a very high frequency of electrical load shedding. Many reasons are being given by officials: COVID-19 related demand and operation change, weather and climate change, mismanagement, corruption, socio-economic growth and so on. Sudden change in lifestyle has dramatically increased the residential electricity and reduced electricity demand in business and industry and that eventually affects the national energy demand profile (Elavarasan et al., 2020). Several studies and analyses started exploring the COVID-19 impact on the power sector, both in the shorter and longer terms (Bompard et al., 2020); e.g., in Europe, Bompard et al. (2020) evaluated the immediate impacts of COVID-19 on European electricity systems while Kirli et al. (2021) assessed the impact of COVID-19 lockdown on the electricity system of Great Britain with a study on energy demand, generation, pricing and grid stability. In Russia, Proskuryakova et al. (2021) proposed a visionary Smart Energy scenario that envisages structural changes in the industry with a focus on clean energy to offer a post-COVID-19 energy response. In the USA, Ruan et al. (2020) released a first-of-its-kind cross-domain open-access data hub, integrating data from across all existing US wholesale electricity markets with COVID-19 case. Kanitkar (2020) assessed the impact of COVID-19 lockdown on Indian economy and power sector. In Africa, Edomah and Ndulue (2020) analysed the role of forced lockdowns on electricity consumption behaviour and its effect on momentary transition in electricity use in Nigeria. However, many other regions in Africa are unevaluated after the lockdowns and the impact of a pandemic such as the one experienced with COVID-19 is still unclear.

As happening in many underdeveloped countries, energy sufficiency is facing problems such as high fuel prices, lack of electricity power projects, inefficient way of producing and distribution of electricity shortage of oil distribution (Jamil and Faran, 2018) that will definitely lead to electrical load shedding and its relationship with safety and security is very close. Medical equipment often requires a continuous power supply (Stawowy et al., 2021), a lack of electrical energy will be fatal for patients. After power shortage, the electric current often comes back with very high intermittent values, consequently households and inhabitants are facing electrical related accidents. Electrical shocks or related explosions are significant causes of occupational death in the world. Hence, there is a need to assess the impacts of load shedding on people's safety and security, to prepare a most effective and reliable response plan.

Some researchers have studied causes and consequences of electrical load shedding on economic and social life. In China, Ou et al. (2016) made a quantitative assessment of the economic impacts of power shortage. In Pakistan, Jamil and Faran (2018) evaluated the impact of electricity and gas load-shedding on social, economic and psychological well-being of factory workers using a quantitative method. Zaman (2017) used a survey questionnaire to show the effects of load shedding on 262 retail businesses in Hyderabad, whereas Arslan et al. (2014) assessed the consequences of energy on routines of people and also on social and economic performance of people. In Africa, Umar and Kunda-Wamuwi (2019) interviewed 200 households and 14 SMEs from Ng'ombe and Kalingalinga to explore how residents and SMEs of Lusaka have been affected by the recent spate of load shedding in the city, Tikuneh (2018) identified system vulnerabilities in the Ethiopian electric power system and Ukpong (1976) realised an analysis of causes of power shortage in Nigeria. However, none or very few have scientifically investigated the safety issues while there is energy shortage; besides, the chosen case of Cameroon is different as it has many unidentified and independent variables that can affect the power sector in the country.

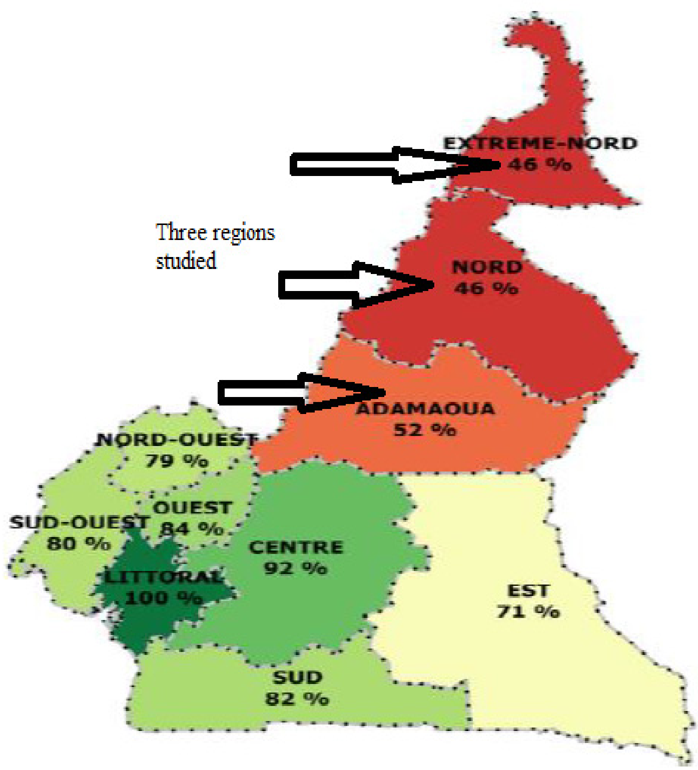
In this paper, the evaluation of the fall 2020-spring 2021 electrical load shedding on Cameroon's northern interconnected electrical grid (NIG) is presented. The main causes are identified and assessed, a safety impact study on poor households and hospitals is performed and some solutions and proposals for a better energy management are given. The first contribution of this paper is to find out and classify the reasons that led to load shedding and evaluate the effects of COVID-19 on demand and operations on the NIG using graphical mathematical tools and data comparison with previous years, decision maker's survey from the ministry of energy and national grid managers. Secondarily, the security and safety consequences of load shedding is assessed and discussed with different stakeholders of the electrical energy mix, including the generators, law makers, domestic consumers and poor area hospitals; we present the safety and security impact of load shedding on households first, then on hospitals in the three main regions of Northern Cameroon while evaluating safety standards (safety knowledge, safety behaviour), using a systematic survey and mathematical tools such as SEMs (structural equation models). The paper is presented as follows: Section 2 presents materials and methods used for this study and Section 3 the results and findings. Discussions and analysis are presented in Section 4, while recommendations are given in Section 5. Finally, Section 6 concludes the paper.

2 Materials and methods

2.1 State of the Art of Cameroon's NIG (northern interconnected grid)

The public power network in Cameroon is divided into three main sectors: The Southern Interconnected Grid (SIG) covering all the southern part of the country, the eastern interconnected network covering the east region, the northern interconnected grid covering the three northern regions (see Figure 1) and many mini-off-grids owned by some independent power producers. Installed capacity is estimated at 2327 megawatts (MW), for a total production of 7696 (GWh), transmitted along 37,194 km of power lines however, less than 1400 MW still in service. The National Electricity Transmission Company (SONATREL) has overseen this operation since October 2015. However, ENEO is charged with managing electricity distribution in Cameroon and ARSEL is the electricity regulator. The national grid access rate in Cameroon was 62% in 2014, with an urban electrification rate of 96% and rural electrification rate of just 35% (USAID, 2019).

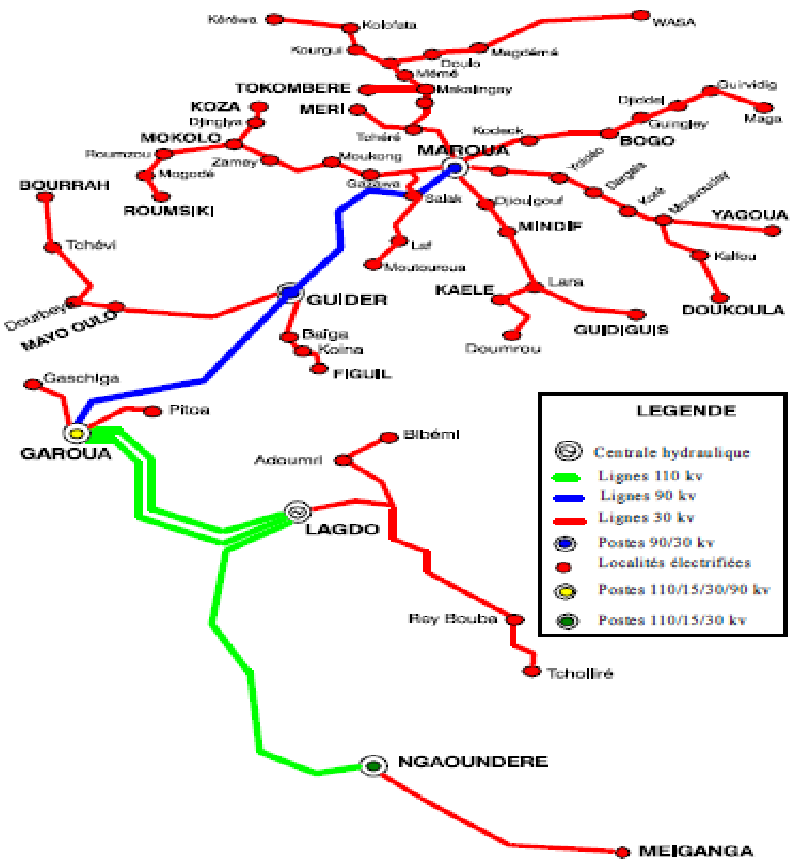
Figure 1 Cameroon's three studied regions



Source: The World Bank (2018)

Since October 2020, the NIG (see Figure 2) has been facing very high frequencies of power load shedding that even led to many protestations off and online. The NIG with its 110 kV and 90 kV structures dispatches the power generated by Lagdo power station to cover the region's modest demand which barely covers 25% of the maximal power that the transmission lines can support (Cameroon MINEE, 2006). On the other side, the installed power on the NIG is presented in Cameroon MINEE (2006) as followed: The Lagdo hydropower station has 72 MW installed, Garoua-Djamboutou Diesel Generators can produce 20 MW, Maroua Diesel Generator supports the NIG with a modest 10 MW installed power. It can be noted that there is a 1 MW diesel installed in N'Gaoundere, and three isolated PowerStations (4 MW) in Kousseri, Poli and Touboro, all out of service.

Figure 2 Cameroon NIG structure



Source: (Cameroon MINEE, 2006).

Although the NIG transmission lines can support the installed power for now and even more years to come, some transformers are old, and some power lines are attacked by corps and violent weather conditions. The three northern regions of Cameroon host 1.2 million out of the 5.6 million non-electrified people in the country (USAID, 2019); For the 2015–2019 five-year period, prospects of an increase in demand according to ENEO, aggregate electricity demand in Cameroon shall reach 8.119 GWh in 2019, representing an annual average growth of 5.7% (ARSEL, 2015). For the NIG, an average of 70% of households do not have access to power, and with the annual population growth at 2.2%, the electricity demand will also increase at a rate of 10%. As demand is increasing while the generation is almost not (2.2%) (The World Bank, 2018), it is clearly understandable that a deficit of energy supply in the three regions might happen.

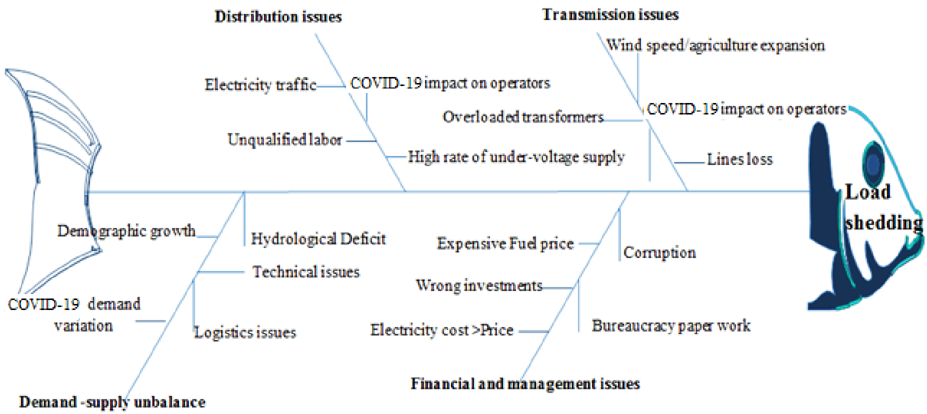
Using authors' experiences (electrical engineers and professor in energy management), pre-interview with the experts and issues sorted out by previous studies such as Tikuneh (2018), Ukpong (1976), Jasiūnas et al. (2021), Qasim and Kotani (2014), Freeman et al. (2020), Waseem and Manshadi (2020) added to the Minister of Energy and Water resources testimonial on national TV (Actualite hebdo on the 21st of February 2021). The Cameroon's NIG issues can be resumed as: 1-Supply-demand unbalance due to many sub-factors: hydrological problems due to the shortage of precipitations that dropped the water volume of the Lagdo dam from 4 to 2 million cubic metres, hence production goes down from 72 MW to 15 MW; Djamboutou power station generating 14 MW instead of 20 MW and Maroua diesel generators producing 5 MW between midnight and 6 AM; Lagdo Power Station turbines and generators stopped because of technical reasons (silting up dam, spare parts); Fuel transport and logistics issues; Electricity demand variation due to COVID-19; Demand increase due to socio-economic reasons. 2-Transmission issues: Overloaded transformers; Wooden distribution towers destroyed either by wind or animals; Non-availability of spare parts; 30% loss on transmission lines from power station to distribution centres. 3-Distribution issues: COVID-19 effect on operators; Stealing and electricity traffic; Low quality of service (passive under voltage, under frequency); Unqualified distribution workers. 4-Financial issues: Electricity production cost which 200 Xaf is sold at an average of 82 Xaf to customers that leads the government to compensate the difference; High fuel price for the Djamboutou and Maroua Diesel Generators Power Stations (1.5Billion Xaf per week since January 2021); Corruption; bureaucracy mismanagement (Wrong investments).

Electrical energy shortage can cause serious economic, social and safety issues that could be a threat to social security. An analysis of the causes of power shortage is critical for rational allocation of human and capital resources to reduce the safety, economic and social impacts in the most cost and time effective way. A designed fishbone diagram used for cause effect analysis is presented in Figure 3. Combined with Relative Importance Index method, the designed Ishikawa diagram gives a clear understanding and ranking of the different factors that led to the high frequency of power shortage in the three northern regions of Cameroon.

2.2 Methodology

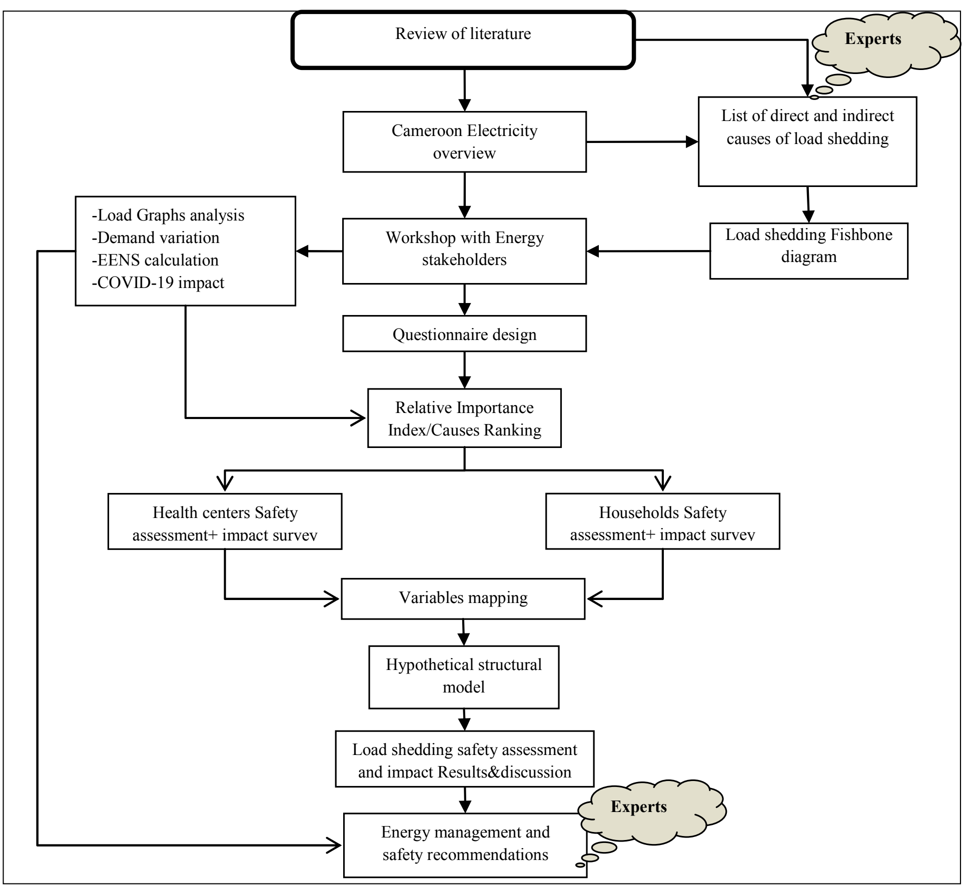
The overall research methodology used is presented in Figure 4.

Figure 3 Fishbone diagram on load shedding causes



Source: Authors.

Figure 4 Adopted research framework



A review of literature was performed from open data, data from grid company and end consumers. This review led to and energy overview and the identification of all load shedding causes in the NIG. After a workshop with all electricity stakeholders, a comparison of load curves and calculation of electricity vulnerability variables was performed; that led to a first conclusion on COVID-19 implication in the power shortage. After having identified and discussed possible causes, a first survey was designed to gather relative importance index of these factors that ended to a ranking from most to least important. Having a clear understanding of the load shedding on the NIG, a consequence evaluation was performed through two surveys from poor households and health centres in the northern regions of Cameroon. Structural equation modelling was used to test the hypotheses of load shedding safety and security impact, compared to safety knowledge and commitment variables. Results were obtained using the software Lisrel and after discussions with experts, some recommendations were made.

2.3 Materials

Two main studies were conducted in this paper.

2.3.1 Load shedding causes analysis was done in six local steps

- Step 1 – demand variation pre-post COVID-19.
  - Power system analysis comparing power profiles and demand pre and post pandemic; Load demand in NIG during COVID-19 lockdown period in 2020 compared to the same in 2019 and 2021.
  - Average Daily Load Profile (ADLP) is evaluated for three years. The ADLP is the defined as the mean load for each step during the days in a selected timeframe (Bompard et al., 2020).
  - A difference between supply and demand is done by estimation of the Expected Energy Not Supplied (EENS) and Expected Demand Not Supplied (EDNS) is done using equations (1) and (2) derived from formulas proposed by Beyza et al. (2020).

$$\text{EENS}=\frac{\sum_{i=1}^{N_y}\sum_{j=1}^{N_i}E_{j,i}}{N_y} \quad (1)$$

where $E_{j,i}$ is the energy not supplied (MW) to the electrical network in the *j*-th power interruption in year i, N_y is the total number of years simulated and N_i is the total number of interruptions in year i.

$$\text{EDNS}=\frac{\text{EENS}}{8760} \quad (2)$$

where 8760 represents the number of hours in a year.

  - Pre-post pandemic demand variation is computed by a formula below as done by Bompard et al. (2020) in equation (3), then it could be possible to estimate the number of years needed for supply to meet demand. The demand variation

(D_v) in the year Y_n (2020) of COVID-19 with the previous year Y_{n-1} (2019) is reported as:

$$D_v = \frac{D_{yn} - D_{yn-1}}{D_{yn-1}} * 100 \tag{3}$$

where D_{yn} and $D_{yn-1} D_{yn-1}$ are the total demand in the examined timeframe of the years Y_n and Y_{n-1}.

- Step 2 – Temperature and precipitation effect using graphical evaluation on pre-post COVID-19 demand for years 2019, 2020 and 2021.

A) Temperature vs. demand; B) Precipitation vs. Demand;

- Step 3 – Relative Importance Index method was chosen to statistically rank the potential factors presented on the Ishikawa Diagram (see Figure 3), from most to least important. Some researchers previously used this simple tool to assess a cause and effect relationship and impact such as Damoah (2020) who sorted out and classified reasons of government projects failure in Ghana using RII, and Salhi et al. (2018) who identified and ranked factors that led to delay in construction projects in Algeria. For this part of the study, Relative Importance Index was coupled with a decision matrix; workshops and interviews were organised with five experts including one of the authors (electrical engineer), a manager at the ministry of energy and water resources, ENEO, ARSEL and SONATREL giving a hundred cumulative years of experience. A first questionnaire was given to the experts, with a list of all factors cited previously that led to the fall 2020 power shortage in the NIG. The experts, as decision makers, had to provide the severity ratings for each of the 19 possible causes of the Cameroon's NIG load shedding, outlined in the questionnaire using a five point Likert Scale; where 1= insignificant factor; 2= minor factor; 3= moderate factor; 4= major factor; 5= catastrophic factor. We note that the likelihoods for all causes were considered to be almost certain and the Relative Importance Index (RII) was calculated using equation 4 (as outlined in Damoah (2020) and Salhi et al. (2018)).

$$RII = \frac{\sum_{i=1}^{5} P_i U_i}{N(n)} \tag{4}$$

where *RII* = relative importance index, P_i = respondent's rating of cause of project failure, U_i = frequency of respondents placing identical rating on the cause of project failure, *N* = sample size (number of DMs), *n*=the highest attainable score on cause, which in this case is *i*= 1, 2,3,4,5.

- Step 4 – Conclusions on COVID-19 and other factors implication in demand variation are drwan.
- Step5 – After having the rankings and graphs comments, factors that mostly affected the load shedding can be sorted out; COVID-19 and other factors impact on the grid can be discussed, guided by the decision matrix as used by Michelez (2010). This can also help for drawing conclusions and remedial recommendations.

2.3.2 Load shedding safety and security impacts analysis on poor hospitals and households

A. *Sampling and data collection*: A non-probabilistic sampling was used for this research, as poor areas had to be considered to meet the objectives. This study was done using two cross-sectional surveys within two samples. The first sample was district hospitals in poor areas of Garoua, Maroua and N'Gaoundere cities, whereas the second sample considered poor households in the three northern regions of Cameroon. A sample of 30 district hospitals (ten in each of the three regions (Far-north, North and Adamawa)) was determined to answer a first semi-structured questionnaire. A team of three bilingual researchers (French and Fulani) was appointed to conduct the questionnaires at the hospitals. The head doctor of each health centre was asked about load shedding effects on their work and their patients' safety and security. Four major groups of questions were asked to them. The first group of questions assessed hospitals' basic information (Region, number of staff); The second group of questions assessed load shedding information (number ,length and time of load shedding per week, whether respondents have a secondary power supply and if they know how to operate it in case they do have one) and customer satisfaction (identical questions as for households below).The third group of questions was about alternative risk factors of safety knowledge and safety attitude and commitment (whether or not have an extinguisher, electrical grounding, whether or not they have hazardous exposure related to electricity); The fourth group of questions assessed safety-health-hygiene-security and direct impact of load shedding on hospital work. Respondents were asked to rate severity (scoring from 1 to 7) depending on how they think the power shortage affects the statement, as presented in Table 1 for Impact on Health Centre's patient care (Ihpc) variables.

A second sample of 463 households was questioned about power shortage situation in their homes and the effects on their personal security and safety. Some of the respondents were asked a two-page questionnaire by the researcher's team that had to go house by house in poor areas of each of the three northern cities to collect answers. An online questionnaire has also been established to gather all the data needed from targeted respondents living in these cities that had an Android phone. Thirty seven questions grouped in four major topics were asked. Similarly, as done for the health centres survey, the first group of questions assessed households basic information (Region, number of people living in the house, whether or not they have a contract with the electricity company, and their average electricity bill); The second group of questions assessed load shedding information (number ,length and time of load shedding per week, whether they have a secondary power supply and which one do they use) and customer satisfaction (whether or not ENEO respects their load shedding program, their preferred load shedding time , whether they think their bill is in accordance with their energy consumption, whether load shedding affects the water and mobile networks distribution systems); the third group of questions was about alternative risk factors of safety knowledge(whether or not anyone in the household has a first aid training, added to two TRUE or FALSE questions on what to do in case of danger, electric shock or fire) and attitude and commitment (whether or not they have a medical box, medical insurance, an extinguisher, electrical grounding, whether or not they have ever trafficked their electricity meter, slept with candles, moon tiger (mosquito coil),whether or not they have hazardous exposure related to electricity (uncovered electrical wires in rooms or toilets, uncovered outlets, household appliance with poor electrical contact)); The last group of questions assessed safety-health-hygiene-security impact (respondents were asked whether or not they have ever been victim of assault during a load shedding, whether power shortages affect their personal hygiene, whether they experienced an increase of insect bites (mosquitoes) due to power cuts, whether household appliances got damaged due to strong or untimely return of electric current or if they experienced small sparks when the electric current returns with a high intensity; They were also asked if they have experienced a fire linked to a load shedding or a strong return of the current ,whether they ever had injuries related to the power cut or return (electric shock, minor accidents, explosions), or if they have witnessed deaths related to the power cut or return due to an explosion ,fire or electric shock). The questions mapping for each group are listed in Table 1.

Table 1 Structural variables mapping and explanation

Latent Variable	*Measurement Variable (Features)*	*Item*	*References*
Load Shedding Variables (LSv)	Load shedding frequency per week Load shedding time Load shedding length Do you think ENEO respect their load shedding schedule?	Lsv1 Lsv2 Lsv3 Lsv4	Zaman (2017) and Pasha and Saleem (2013)
Demographic and socioeconomic variables (DEv)	Number of people at home Monthly electricity bill Do you have your own energy meter or not? Alternative sources of energy used during load shedding	DEv1 DEv2 DEv3 Dev4	Nilson and Bonander (2020); Shobande (2020) and Mukherjee et al. (2018)
Safety knowledge (Sk)	Does anyone at home know about first aid? Safety knowledge assessment1 Safety knowledge assessment2	Sk1 Sk2 Sk3	Khosravi et al. (2014a, 2014b)
Safety attitude/ commitment (Sac) attitude	Do you have an extinguisher at home? Do you have a first aid box at home? Do you have a life Insurance? Do you have grounding in you electrical system? Do you use moon tiger insecticide? Have you ever slept with candles turned on? Do you have electric wires on the ground at home? Do you have uncovered electric wires in your toilets Do you have opened sockets at home? Have you ever got shocked by your fridge TV or washing machine?	Sac1 Sac2 Sac3 Sac4 Sac5 Sac6 Sac7 Sac8 Sac9 Sac10	Khosravi et al. (2014b)

Table 1 Structural variables mapping and explanation (continued)

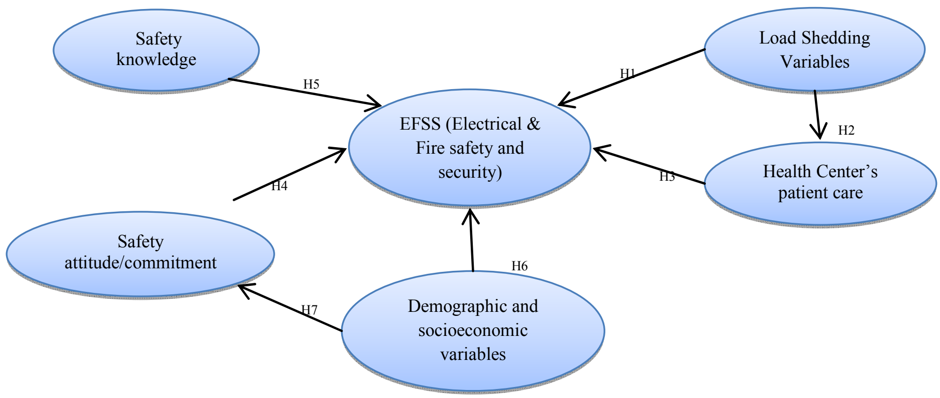
Latent Variable	*Measurement Variable (Features)*	*Item*	*References*
Impact on Health Centre's patient care (Ihpc)	Impact on care given to patients	Ihpc1	Shobande (2020) and Wu et al. (2013)
	Impact on communication	Ihpc2	
	Impact on sterilisation of medical instruments	Ihpc3	
	Fresh packaging of products	Ihpc4	
	Impact on medical equipment	Ihpc5	
	Impact on laboratory diagnostics	Ihpc6	
	Impact on staff motivation	Ihpc7	
	Impact on patients mindset	Ihpc8	
	Risk of worsening or death	Ihpc9	
	Have you ever performed childbirth in darkness?	Ihpc10	
	Have you noticed an increase of malaria patients?	Ihpc11	
	Increase of fire electrical shock accidents patients?	Ihpc12	
	Have you noticed an increase of fatal fire related cases?	Ihpc13	
	Have you noticed any fatal electrical shock related cases?	Ihpc14	
Electrical & Fire safety and security impact (EFSS)	Have you ever been victim of assault during load shedding?	EFSS1	Lawson (2022); Mills (2016) and Zahoor et al. (2015)
	Do power shortages affect your personal hygiene?	EFSS2	
	Have you experienced an increase of insect bites (mosquitoes) due to power cuts?	EFSS3	
	Have you had household appliances damaged due to strong or untimely return of electric current?	EFSS4	
	Have you experienced small sparks due to static electricity or overcurrent when power returns?	EFSS5	
	Have you experienced a fire or explosion linked to a load shedding or a strong return of the current? Electricity (overcurrent) or chemical (candle moon tiger) based fire	EFSS6	
	Have you witnessed injuries related to the power cut or return (electric shock, minor accidents, explosions)	EFSS7	
	Have you witnessed death related to the power cut or return due to an explosion or fire?	EFSS8	
	Have you witnessed death related to the power cut or return due to an electric shock?	EFSS9	

It took nearly six months (From November 2020 to April 2021) to collect the data, and all information obtained from respondents was treated with confidentiality, respecting ethics and laws of the country. The limitations to the study were: time for conducting the research, limited budget for researchers and scalability to conduct the study to a higher range and wider samples. The study used Cronbach's alpha test for reliability testing, which yield an overall reliability coefficient of 92% (93% for hospitals questionnaire and 91% for households questionnaire), implying that the instrument was consistent and reliable in achieving the study objective. The responses collected were grouped under themes used as macro-latent variables (see Figure 5). For an effective presentation of the safety and security effects of power shortage, direct (accidents and insecurity under power shortage) and indirect (safety behaviour and knowledge under unsafe situations) impacts of load shedding were analysed. Structural equation modelling was used to evaluate the safety and security effects of load shedding on poor health centres and households. The relationship between load shedding and accidents rates, safety behaviour and knowledge was assessed. SPSS 25 was used to for general information graphing and Lisrel 8.8 for structural equations modelling.

B. *Use of structural equation modelling*: Structural Equation Modelling (SEM) is a widely used multivariate technique for exploring and testing the relationship between variables (Ajayi and Oyedele, 2018). As this research is a multivariate relationship study, the advantages of SEMs are used to clearly state test and analyse some hypothesis related to load shedding, safety attitude and knowledge and its security impacts on poor households and hospitals. SEMs can also help understand the algorithms that link a causal to effects relationships. Many variables can be analysed at once and the researcher can draw faster and effective conclusions; hence, due to extensive benefits of SEMs, the method is widely used in many research fields especially in risk and a cause-effects analysis. For instance, Ajayi and Oyedele (2018) proposed a structural equation modelling of critical success factors Waste-efficient materials procurement for construction projects. Their study employs sequential exploratory mixed method approach as its methodological framework, using focus group discussion, statistical analysis and structural equation modelling; Also, Boccia and Sarnacchiaro (2014) proposed a structural equation model for the evaluation of social initiatives on customer behaviour, they formalised the origins of behaviours regarding consumers' preferences towards responsible initiatives and detect the drivers of their purchase. To understand the safety and security impact of load shedding and lack of safety behaviour /knowledge in poor households and hospitals in the northern part of Cameroon, a structural equation model was developed.

C. *Designed structural model*: The study employed the questionnaire (see Table 1) in which the items were measured by different scales; It was chosen to set an ordinal scale with five point for variables such as Ihpc1-9 and a dichotomous scale for variables such as Sac1-19. In order to design a hypothetical model for the SEM, this paper has chosen the 44 questions established in Table 1 as measurement variables and six-key group as latent variables. Figure 5 shows the hypothetical structural model for the study.

Figure 5 Conceptual hypothetical-structural model



Integrating these arguments, the following hypotheses were stated and tested for the northern regions of Cameroon:

H1 = EFSS (Electrical & Fire safety and security) is positively significantly affected by load shedding;

H2 = Health Centre's patient care is positively significantly affected by load shedding;

H3 = EFSS (Electrical & Fire safety and security) is positively significantly affected by poor work of healthcare centres under load shedding;

H4 = EFSS (Electrical & Fire safety and security) is positively significantly affected by poor safety attitude/commitment under load shedding hazards;

H5 = EFSS (Electrical & Fire safety and security) is positively significantly affected by lack of safety knowledge under load shedding hazards;

H6 = EFSS (Electrical & Fire safety and security) is positively significantly affected by demographic and socioeconomic variables under load shedding;

H7= Poor safety attitude/commitment under load shedding is positively significantly affected by demographic and socioeconomic variables;

3 Results

3.1 Load shedding causes analysis and classification

Step1 – Demand variation pre-post COVID-19: In a normal year, the power consumption in Cameroons NIG is 400 GWh (33 GWh/month) for an average power of 35 MW (USAID, 2019). The variation of the energy supplied in Figure 6 shows that in year 2019, the average needed energy was supplied. There is a drop of almost 40% of the supplied energy, starting from July 2020 till October 2021 with an average supplied energy of 15 GWh monthly. Similarly, out of the 400 GWh needed in average, Table 2 shows that the Expected Energy Not Supplied in the network has increased from 4.9 GWh in 2019 to 175.9 GWh in 2020 and even 181.93 GWh in 2021. The results in Table 2 also show that in 2020 and 2021, even half of the average normal demand (17 MW) was not met, with an Expected Demand Not Supplied (EDNS) of 20 MW in 2020 and 21 MW in 2021. It should be noted the lockdown due to COVID-19 in Cameroon started in March 2020 and ended in July 2020, thus, a month before the power shortage started.

Figure 6 Energy supplied for three years (2019, 2020 and 2021)

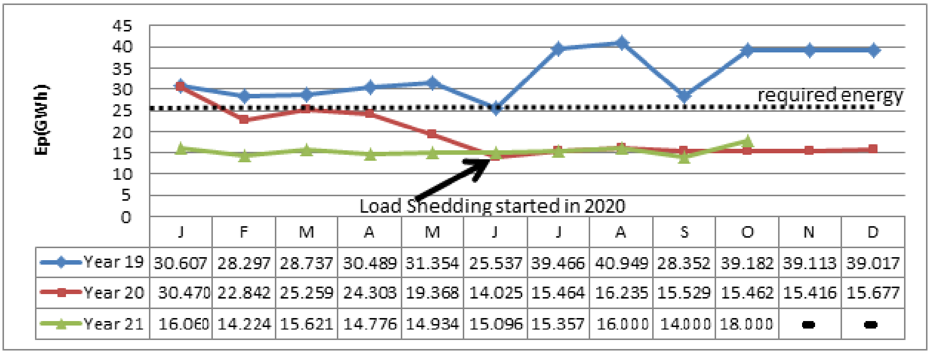
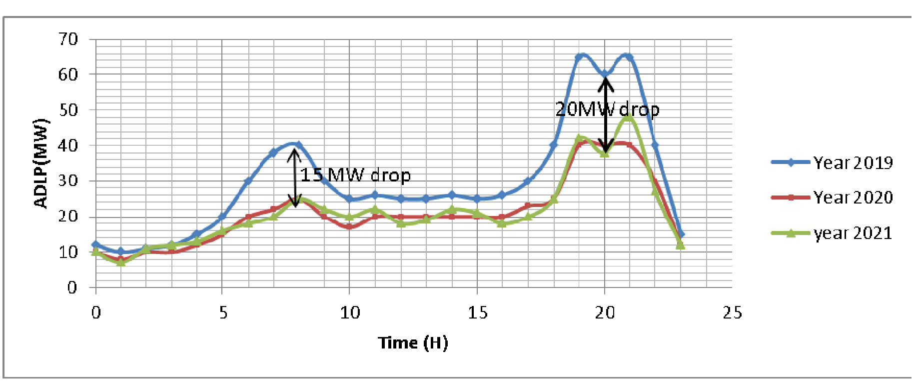


Table 2 Expected energy not supplied in the network

	J	*F*	*M*	*A*	*M*	*J*	*J*	*A*	*S*	*O*	*N*	*D*	*EENS (GWh)*	*EDNS (MW)*
2019	9.60	–6.70	–6.26	–4.51	–3.64	–9.46	4.46	5.94	–6.64	4.18	4.11	4.01	–4.90	–0.6
2020	9.46	–12.15	–9.74	–10.69	–15.63	–20.97	–19.53	–18.76	–19.47	–19.53	–19.58	–19.32	–175.9	–20
2021	–4.94	–20.77	–19.37	–20.22	–20.06	–19.90	–19.64	–19	–21	–17	–	–	–181.93	–21

Figure 7 represents the ADLP for the 30th of June 2019, 2020 and 2021. The behaviour of the ADLP in the case of strict lockdown in 2020 is very similar to the same day chosen in 2021.Changes are observed in demand magnitude and profile with decreased demand directly after the lockdown but continued even after activities went back to normal in 2021.The existing fluctuations in the power demand across all the COVID-19 evolution shows a drop of 20 MW in the peak time (see Figure 7) might suggest causes owing to the effects of pandemic, but a year after, in July in 2021, it is also seen that the electrical load shedding actually continues.

Figure 7 ADLP for a random day in June 2019, 2020 and 2021



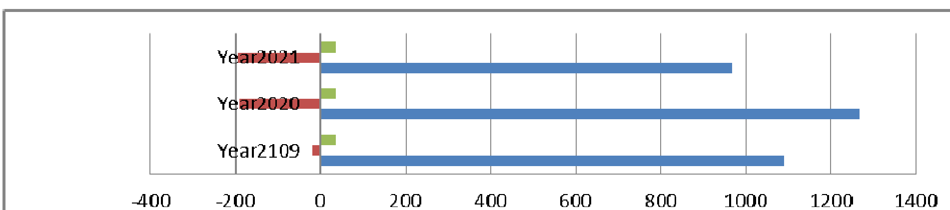
Using the formula stated by equation (3) and data in Figure 6, the mean demand for years 2019, 2020 and 2021 was 33 GWh/month, 19 GWh/month and 15 GWh/month, respectively; the demand variation for the three years can be computed using the following:

$$D_{v2019-2020} = \frac{33-19}{19} * 100 = 74\%; \; D_{v2020-2021} = \frac{19-15}{15} * 100 = 26\%.$$

These results show that even though the demand dropped by 74 points between 2019 and 2020, it continued to decrease after COVID-19 between 2020 and 2021 with a $Dv_{2020-2021}$ =26%.

Step 2 – Temperature and precipitation: As mentioned in previous sections, much of the energy supplied in the studied region comes from the only Lagdo hydropower station, so there is a great seasonal and annual variability in power balance by changes in precipitation and temperature. Figure 8 shows the variations of temperature (green bars), precipitations (blue bars) and the energy not produced for the years 2019, 2020 and 2021.The results show that the average temperature variation for the three years is very low (T2019=34.6°C, T2020=34.75°C, T2021=34.33°C), thus a very low influence of temperature in energy generation. For the year 2020, the results reveal a contradiction with expert's opinion (see Table 3) who believe that hydrology is highly positively related to power shortage; Even though the year 2020 recorded a higher rate of precipitations (1268 mm), the expected energy not supplied is also high: 189 GWh out of the 400 GWh needed in average. Moreover, it is assumed that generation from diesel power stations was utilised maximum as the hydropower station operation was at the lowest. Hence, the influence on the curve between pre-COVID-19 and after-COVID-19 might come from technical reasons. These results show a very slight influence of temperature, climate change and COVID-19 in the 2020 electrical load shedding in Cameroon's NIG.

Figure 8 Temperature and precipitation against energy not supplied



	Year2109	Year2020	Year2021
T(°C)	34.6	34.75	34.33
ENP(GWh)	-18.9	-189.9	-195.93
P(mm)	1090	1268	967

Step 3 – Causes classification and ranking: From the results in Table 3, it can be seen that the most important factor that led to load shedding in Cameroon's NIG is the issue of electricity production cost which is higher than market price, leading the government to induce additional expenses to cover the financial gap. Secondly, multiple wooden distribution towers in the country side were destroyed either by wind or animals highly impacting the transmission system, hence hugely affecting load shedding. The non-availability of spare parts in thermal power stations is ranked third; the absence of spare parts when there is equipment failure in power production will negatively impact the effective production of electricity. At the fourth and fifth ranks, respectively, the hydrological deficit due to the shortage of precipitations and silting up or obsolete turbines in Lagdo Power Station directly affect the demand and supply balance and create a deficit in terms of electricity generation, hence leading to an obvious load shedding. In terms of causes categories, it is found that transmission issues affect the most load shedding with a RII=3.4, followed by supply-demand unbalance (RII=3.08), then financial issues (RII=2.96). It is found that distribution issues affect the least power shortage (RII=2.475). In accordance with the graphical and formulas results, electricity stakeholders believe that COVID-19 did not have a huge impact on the 2020–2021 electrical load shedding in Cameroon, neither from demand variation, nor from effects on energy service operators.

Table 3 Load shedding causes ranking by experts

Issues Categories	*Load shedding factors*	*1*	*2*	*3*	*4*	*5*	*RII*
Demand-Supply Unbalance RII 3.08	Demand increase due to socio-economic reasons	0	2	2	0	1	3
	Electricity demand variation due to COVID-19	1	2	1	1	0	2.4
	Hydrological deficit due to the shortage of precipitations	0	1	2	1	1	3.4
	Fuel transport and logistics issues.	0	1	3	0	1	3.2
	silting up or obsolete turbines in power stations	0	0	3	2	0	3.4
Transmission Issues RII 3.4	Overloaded transformers	0	2	2	1	0	2.8
	Wooden distribution towers destroyed either by wind or animals	0	0	2	2	1	3.8
	Non-availability of spare parts	0	0	2	3	0	3.6
	Lines loss	2	3	0	0	0	1.6
Distribution Issues RII 2.475	COVID-19 effect on operators	1	2	1	1	0	2.5
	Electricity traffic	0	2	2	1	0	2.8
	Low quality of service (passive under voltage, under frequency)	0	3	2	0	0	2.4
	Unqualified distribution workers	1	2	2	0	0	2.2
Financial Issues RII 2.96	Wrong investments	1	2	2	0	0	2.2
	High fuel price	1	0	2	1	1	3.2
	Electricity production cost higher than market price	0	0	2	2	1	3.8
	bureaucracy, paper work	0	2	2	1	0	2.8
	Corruption	0	2	2	1	0	2.8

Notes: Extremely serious=5, very serious=4, serious=3, medium=2, low=1.

3.2 load shedding safety and security impact analysis

The studied sample consisted of 463 households and 30 hospitals (10 in each of the three selected regions); household percentage distribution is displayed in Figure 9. In the sample, 15.55% of the households were taken from Adamawa region, whereas 20.24% of the respondents were taken from the North region and finally 54.21% from the Far North region of Cameroon; this result actually follows the production variation result that actually affected the Far North region most, so respondents were enthusiastic to take part in the study. It was found that the commonly named safety and security consequences of load shedding on households were actually relevant. For example, 90.1% of the respondents experienced an increase of insect bites (mosquitoes) due to power cuts. Also 22% witnessed injuries related to the power cut or return (electric shock, minor accidents, explosions),and a cumulative of 27% witnessed death related to the power cut or return due to an explosion or fire or an electric shock. Hence, if respondents were given a choice about power shortage timing, Figure 10 shows that they mostly prefer having load shedding in morning (363 households: 78.4%) or afternoon (62 respondents: 13%) time. Very few would prefer having power shortage in the evening or at night.

Figure 9 Respondents participation per region

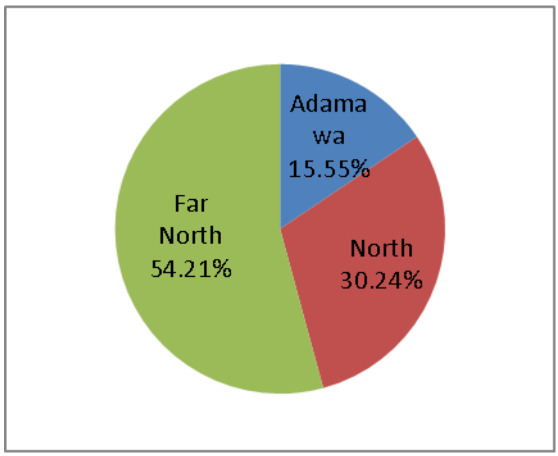
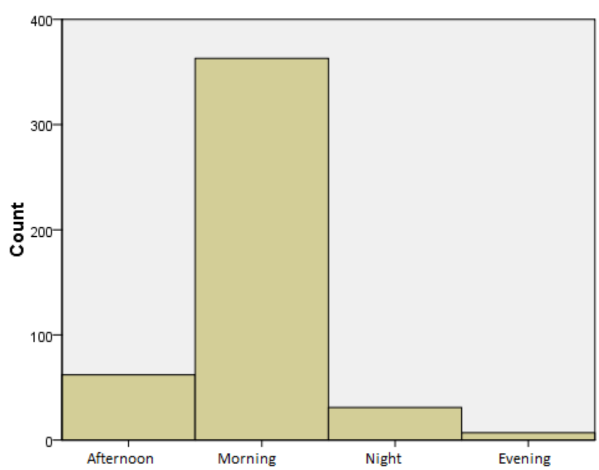


Figure 10 Households load shedding time preference



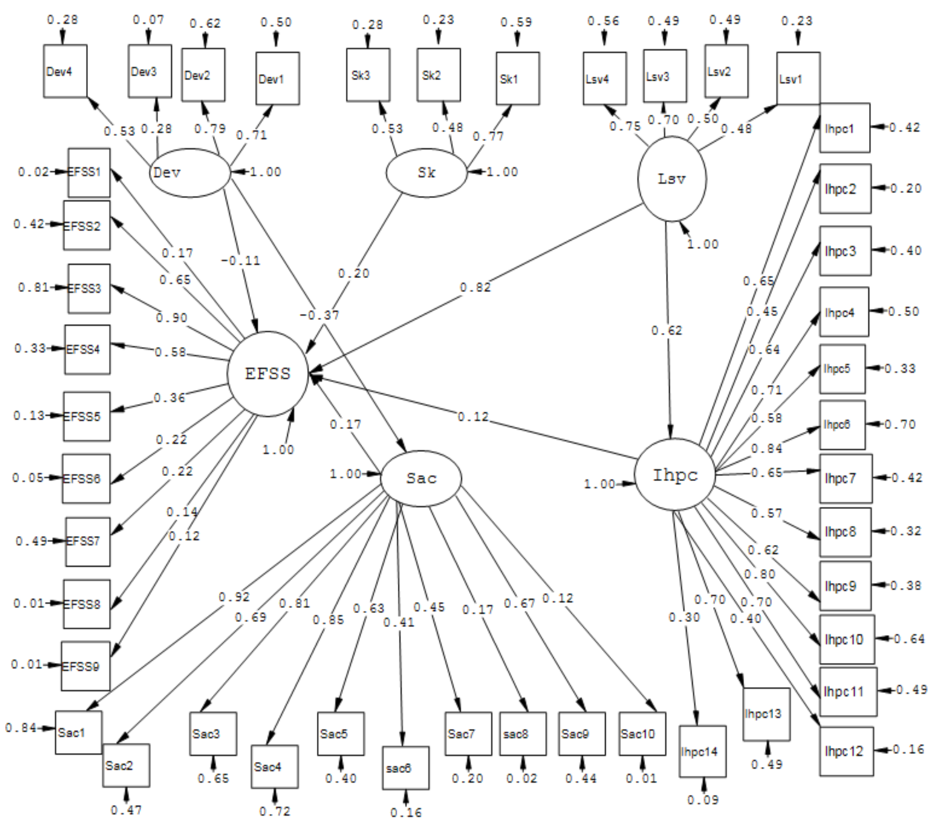
The Cronbach alpha analysis was calculated using SPSS 26 to test if all the measured variables are contributing to their latent variables and to confirm the questions mapping. The study was implemented to be used with the covariance-based SEM. As shown from

Table 4, the values of alpha were 0.89 for demographic and socioeconomic variables, 0.96 for safety knowledge, 0.84 for safety attitude/commitment, 0.92 for load shedding variables, 0.9 for electrical and fire safety and security impact and 0.93 for health centre's patient care, all beyond the recommended 0.79. The overall value of alpha was 0.9.The model computed in Figure 11 had an acceptable fit to the data for both indicators (x^2/d.f. and GFI) for all latent variables as shown in Table 4, and the model fit indices satisfy the conventionally acceptable levels $\chi 2$/d.f. = 1.88, p=.005, (n = 463) and GFI = 0.94.

Table 4 Reliability indicators

Latent variables	*Alpha α*	*Chi-Square x^2/d.f.*	*Goodness of fit (GFI)*
Demographic and socioeconomic variables	0.89	1.31	0.97
Safety knowledge	0.96	1.24	0.88
Safety attitude/commitment	0.84	2.45	0.92
Load shedding variables	0.92	1.75	0.98
Electrical & Fire safety and security impact	0.90	2.03	0.91
Health Centre's patient care	0.93	1.25	0.95
Overall model	0.90	1.88	0.94

Figure 11 SEM results (for $\chi 2$/df=1.88, p=.005, n=463)



As shown in Figure 11, the latent variables of the model were the six constructs under this study (load shedding variables(LSv), demographic and socioeconomic variables (DEv), Safety knowledge (Sk), safety attitude/commitment (Sac), impact on health centre's patient care (Ihpc) and Electrical & Fire Safety and Security impact (EFSS)) and the composite scores of their respective dimensions were used as manifest indicator variables receiving loadings from these latent factors as performed by Ajayi and Oyedele (2018) in their research. For example, load shedding variables (LSv) consisted of six factor variables computed by averaging their items of the corresponding factor. Figure 11 shows the model corresponding path coefficients, and Table 5 presents the standardised coefficient estimates of the model using a one-tailed test ($p < .05$) to study the impacts between variables.

Table 5 Coefficient estimates of the hypotheses model

Hypothesis	*Coef.*	*Pvalue*	*Decision*
H1 = EFSS (Electrical & Fire safety and security) is significantly affected by load shedding;	0.82	p<0.01	Supported
H2 = Health Centre's patient care is significantly affected by load shedding;	0.62	P<0.04	Supported
H3 = EFSS (Electrical & Fire safety and security) is significantly affected by poor work of healthcare centres under load shedding;	0.12	p<0.01	Supported
H4 = EFSS (Electrical & Fire safety and security) is significantly affected by poor Safety attitude/commitment under load shedding hazards;	0.17	p<0.01	Supported
H5 = EFSS (Electrical & Fire safety and security) is significantly affected by lack of safety knowledge under load shedding hazards;	0.20	p<0.05	Supported
H6 = EFSS (Electrical & Fire safety and security) is significantly affected by demographic and socioeconomic variables under load shedding;	–0.11	p<0.01	Rejected
H7= Poor Safety attitude/commitment under load shedding is significantly affected by demographic and socioeconomic variables;	–0.37	p<0.01	Rejected

Among the five latent factors namely load shedding variables (LSv), demographic and socioeconomic variables (DEv), safety knowledge (Sk), safety attitude/commitment (Sac), impact on health centre's patient care (Ihpc), demographic and socioeconomic variables (DEv) were found to have a negative relationship with electrical & fire safety and security impact (EFSS) with a standardised coefficient of –0.11. Meanwhile, the four factors such as LSv, Sk, Sac, Ihpc (with standardised coefficient of 0.82, 0.2, 0.17 and 0.12, respectively) were found to have positive relationship with electrical & fire safety and security impact (EFSS). It is also suggested that load Shedding variables (LSv) strongly impact health centre's patient care (Ihpc) (with standardised coefficient of 0.62) but demographic and socioeconomic variables (DEv) have no positive impact on respondent's unsafe attitude/commitment (Sac) (with standardised coefficient of –0.37). Thus, as shown in Table 5, five of the hypotheses (H1, H2, H3, H4 and H5) were significantly supported at 95% confidence level; two hypotheses (H6 and H7) were rejected.

4 Discussion

One of the objectives of this study was to assess the main reasons for the power shortage in north Cameroon. Oppositely to the results of Bompard et al. (2020) who found that lockdown measures to fight back the COVID-19 pandemic took a significant toll on European power, curves comparison in Figure 6 show that it was not the case in Cameroon. According to this study, the pandemic did not have a significant effect on the 2020–2021 electrical load shedding. Also the influence of precipitation and temperature was seen to be very slight on demand variation. Instead, the results have shown that power transmission issues in different lines are the most important factors noticed. The use of wooden distribution towers is seen to have the highest impact on power outage as they are destroyed either by wind or animals. Also, the lack of spare parts on turbines and generators is inducing a huge impact on supply chain, thus a liability to power generation. Similarly to much of the third world countries, Cameroon also presents huge financial and political issues that induce higher risks on project completion and electricity supply reliability. Thus, proactive and efficient power shortage mitigation strategy is needed.

The other main objective of the present research was to explore the safety and security impact of electrical load shedding using variables relationship evaluation. The results of Structural Equation Modelling (SEM) using data from a survey of 463 households and 30 district hospitals in Northern Cameroon have shown that the impact is actually serious. The results of this study supported five of the seven proposed hypotheses. As showed in Figure 11, the four variables of load shedding (LSv1=Load shedding frequency, LSv2=Load shedding time, LSv3=Load shedding length and LSv4=respect of load shedding schedule) do contribute to a significant impact on households and hospitals safety and security with a loading factor of 0.82 and $p<0.01$.It is also reported a very high correlation between power shortage and patient care in district hospitals (load factor=0.62 and $p=0.032$) as recorded in Table 5. Variables such as LSv3 and LSv4 loaded with factors of 0.75 and 0.74, respectively are seen to be more implicated in safety and security issues in households and hospitals. Moreover, this result is similar with the results Arslan et al. (2014) found that power shortage frequency is highly implicated in social accidents while studying the impact of CNG load shedding on daily routine in Pakistan, and the results found by Lawson (2022) while assessing fire related accidents following power outages in Cape Town.

With a loaded factor of 0.12 and $p<0.01$, it is found that Electrical & Fire Safety and Security (EFSS) impact is positively but not significantly affected by poor work of healthcare centres under load shedding. In other words, even though power shortage is highly affecting patient care in district hospitals, the low quality of care does not have significant impact on population's safety. This is in line with the earlier finding of Wu et al. (2013) that proved a positive correlation between patient care and safety in the USA, Japan and Taiwan. The slight correlation can be explained by the highest impact of load shedding on laboratory diagnostics and performing childbirth in darkness which is actually risky but not deadly, according to hospital head doctors.

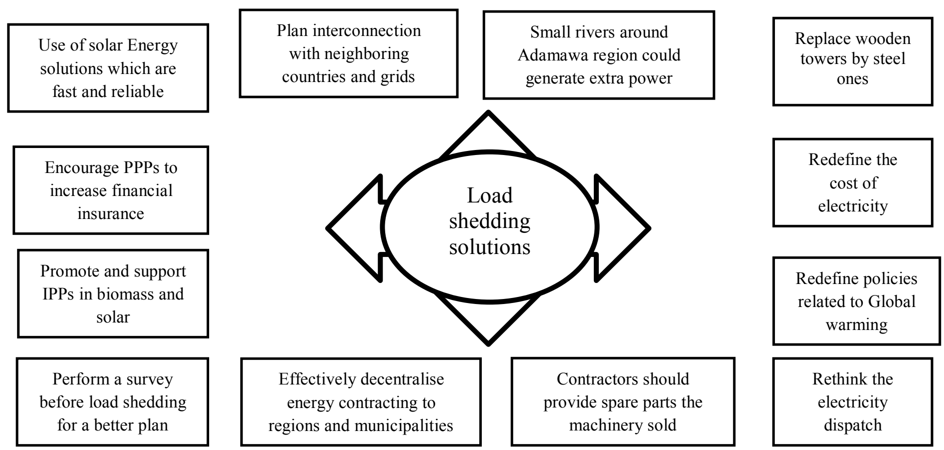
The results in Table 5 and Figure 11 also show that EFSS is significantly affected by both lack of safety knowledge and wrong attitude/commitment under load shedding hazards; with a loading factor of 0.2 and $p<0.05$, safety knowledge is implicated in safety and security risk increase under power outage. When asked if they have any knowledge on first aid, it was found that most of the households answered negatively (loaded factor of Sk1=0.77). This has induced the implication of knowledge in safety and security impact in darkness. While assessing safety attitude under load shedding, it was found that the loading factor of 0.17 is explaining its effective implication in safety and security under load shedding. For example, Mills (2016) found that more than 40% of 0 to 4-years-child deaths in Lagos-Nigeria are caused by kerosene lamps used by families under load shedding. Comparatively in this study, the variable Sac6 loaded with a factor of 0.41 is seen to be highly impacting households' safety under power shortage. The analysis of Figure 11 and Table 5 also shows that demographic and socioeconomic variables (loading factor =–0.11, $p<0.01$) negatively affects safety and security under power shortage. However, this result is opposite to the one found by Shobande (2020) who stated that urban population rate has a positive correlation with infant mortality rates in Africa when unconventional energy is used in households. With a loading factor of –0.37 under a probability $p<0.01$, it is found as reported in Table 5 that there is a negative correlation between poor safety attitude/commitment under load shedding and demographic and socioeconomic variables; in other words, the safety attitude of respondents under power shortage is not defined by the number of people in the household nor by the income. Oppositely, Nilson and Bonander (2020) using evidence from a Swedish survey, showed significant correlations between the level of fire protection and a range of factors (family composition, income, housing type), suggesting a positive effect of socioeconomic success.

5 Recommendations

Some recommendations would help utilities to handle the current scenario and some need to be taken up to overcome impacts arising from any unforeseeable scenarios in future and thus keep supporting a sustainable growth in the energy sector. A framework of the proposed recommendations is presented in Figure 12, following the causes ranking and assessment discussed earlier. The methodological results of this study can help decision makers to mitigate power shortage and establish a roadmap of energy management in Northern Cameroon. Based on responses by the sample of households on Figure 10, 78.4% of respondents prefer power outage in morning time. Households report that changing load shedding times to earlier in the day before finding permanent solutions would be less disruptive, as most schools and offices have generators. As COVID-19 pandemic has no important effect on power shortage in Cameroon's NIG, the energy response plan should be independent from the health factors in the short term. The long-term effects of the COVID-19 crisis will be mostly associated with economic recession, thus an energy response plan should be compliant with economic and strategic plans.

Furthermore, this study contributes to a customised body of safety by assessing alternative methods of improving safety at home and hospitals. The results suggested average safety knowledge and attitude at home and hospitals. Thus, Governments should include a safety class from basic education to college and add first aid advertisements in TV shows. The fire department should undergo more research on safety at home, and prepare a safety response plan. The electricity distribution company should design strategies to provide workers with education and training that is adapted to their personal and occupational circumstances to protect them against electrical risks and include safety as a performance parameter at work. The results also suggest that the competent authorities must promote actions to verify that the installations and equipment used comply with applicable legislation regarding protection against direct and indirect electrical contact and fine customers that do not respect safety standards. Parents should educate their children to the importance of safety behaviour and knowledge through educational talks and safety games for children.

Figure 12 Proposed recommendations



6 Conclusion

In this study, we have shown how the use of wooden distribution towers, the lack of spare parts on turbines and generators, and financial and political issues induce higher risks on electricity supply reliability. This study has also shown that lockdown due to the COVID-19 pandemic did not directly participate in the energy crisis and changes in electricity demand patterns in Cameroon's NIG; instead, it led to an economic recession that might affect future energy plans. We also see how load shedding seriously affected safety and security of the population both at home and at the hospital especially for poor areas. Indeed, it is important for governments and communities to re-evaluate the policy used in managing and shaping energy solutions that will lead to permanent solutions. This research has also proved a severe safety and security impact of load shedding on poor households and hospitals. This has induced the implication of safety knowledge in security impact under power shortage. Therefore, there is need for a safety education scheme with the intention of improving behaviours both at home and at the work place. One of the limitations of this research is the limited sample of the data and the lack of government concern in the surveys. Future research may involve the whole country, using a bigger sample and getting officials' involvement.

References

Ajayi, S.O. and Oyedele, L.O. (2018) 'Waste-efficient materials procurement for construction projects: a structural equation modelling of critical success factors', *Waste Management*, Vol. 75, pp.60–69. Doi: 10.1016/j.wasman.2018.01.025.

ARSEL (2015) *2015-Activity-Report*.

Arslan, M., Zaman, R. and Malik, R.K. (2014) 'Impact of CNG load shedding on daily routine: a study of Pakistan', *International Letters of Social and Humanistic Sciences*, Vol. 42, pp.110–120. Doi: 10.18052/www.scipress.com/ILSHS.42.110.

Beyza, J., Gil, P., Masera, M. and Yusta, J.M. (2020) 'Security assessment of cross-border electricity interconnections', *Reliability Engineering and System Safety*, Vol. 201. Doi: 10.1016/j.ress.2020.106950.

Boccia, F. and Sarnacchiaro, P. (2014) 'Structural equation model for the evaluation of social initiatives on customer behaviour', *Procedia Econ. Finance*, Vol. 17, pp.211–220. Doi: 10.1016/S2212-5671(14)00896-X.

Bompard, E. et al. (2020) 'The immediate impacts of COVID-19 on European electricity systems: a first assessment and lessons learned', *Energies*, Vol. 14, No. 1. Doi: 10.3390/en14010096.

Brosemer, K. et al. (2020) 'The energy crises revealed by COVID: intersections of Indignity, inequity, and health', *Energy Research and Social Science*, Vol. 68. Doi: 10.1016/j.erss.2020.101661.

Cameroon MINEE (2006) *Assistance au Ministère de l'Energie et de l'Eau dans l'élaboration du Plan de Développement à long terme du Secteur de l'Électricité Horizon 2030 (PDSE 2030)*, Juillet.

Damoah, I.S. (2020) 'Causes of government project failure in developing countries – focus on Ghana', *International Journal of Managing Projects in Business*, Vol. 11, No. 1. Doi: 10.1108/IJMPB-04-2017-0042.

Edomah, N. and Ndulue, G. (2020) 'Energy transition in a lockdown: an analysis of the impact of COVID-19 on changes in electricity demand in Lagos Nigeria', *Global Transition*, Vol. 2, pp.127–137. Doi: 10.1016/j.glt.2020.07.002.

Elavarasan, R.M. et al. (2020) 'COVID-19: impact analysis and recommendations for power sector operation', *Applied Energy*, Vol. 279. Doi: 10.1016/j.apenergy.2020.115739.

Freeman, G.M., Apt, J. and Moura, J. (2020) 'What causes natural gas fuel shortages at U.S. power plants?', *Energy Policy*, Vol. 147. Doi: 10.1016/j.enpol.2020.111805.

Jamil, M.F. and Faran, M. (2018) 'The impact of electricity and gas load-shedding on social, economic and psychological well-being of factory workers', *International Journal of Research in Humanities and Social Studies*, Vol. 5, No. 12, pp.34–43.

Jasiūnas, J., Lund, P.D., Mikkola, J. and Koskela, L. (2021) 'Linking socio-economic aspects to power system disruption models', *Energy*, Vol. 222. Doi: 10.1016/j.energy.2021.119928.

Kanitkar, T. (2020) 'The COVID-19 lockdown in India: impacts on the economy and the power sector', *Global Transition*, Vol. 2, pp.150–156. Doi: 10.1016/j.glt.2020.07.005.

Kanti Bose, T. (2012) 'Application of fishbone analysis for evaluating supply chain and business process – a case study on the ST James Hospital', *International Journal of Management Value Supply Chains*, Vol. 3, No. 2, pp.17–24. Doi: 10.5121/ijmvsc.2012.3202.

Khosravi, Y., Asilian-Mahabadi, H., Hajizadeh, E. and Behzadan, A.H. (2014a) 'Structural modeling of safety performance in construction industry', *Iranian Journal of Public Health*, Vol. 43, No. 8, pp.1099–1106.

Khosravi, Y., Asilian-Mahabadi, H., Hajizadeh, E., Hassanzadeh-Rangi, N., Bastani, H. and Behzadan, A.H. (2014b) 'Factors influencing unsafe behaviors and accidents on construction sites: a review', *International Journal of Occupational Safety and Ergonomics*, Vol. 20, No. 1, pp.111–125. Doi: 10.1080/10803548.2014.11077023.

Kirli, D., Parzen, M. and Kiprakis, A. (2021) 'Impact of the COVID-19 lockdown on the electricity system of Great Britain: a study on energy demand, generation, pricing and grid stability', *Energies*, Vol. 14, No. 3. Doi: 10.3390/en14030635.

Lawson, K. (2022) 'Electricity outages and residential fires: evidence from Cape Town, South Africa', *South African Journal of Economics*, Wiley Online Library, p.21. Doi: 10.1111/saje.12329.

Michelez, J. (2010) *Risk Quantification in Energy Projects*, ALTRAN, Report.

Mills, E. (2016) 'Identifying and reducing the health and safety impacts of fuel-based lighting', *Energy Sustainability Development*, Vol. 30, pp.39–50. Doi: 10.1016/j.esd.2015.11.002.

Mukherjee, S., Nateghi, R. and Hastak, M. (2018) 'Data on major power outage events in the continental U.S.', *Data Brief*, Vol. 19, pp. 2079–2083. Doi: 10.1016/j.dib.2018.06.067.

Narcisa, C.A. (2014) 'A possible approach of course design', *The Procedia – Social and Behavioral Sciences*, Vol. 128, pp.228–233. Doi: 10.1016/j.sbspro.2014.03.148.

Nilson, F. and Bonander, C. (2020) 'Household fire protection practices in relation to socio-demographic characteristics: evidence from a Swedish National Survey', *Fire Technology*, Vol. 56, No. 3, pp.1077–1098. Doi: 10.1007/s10694-019-00921-w.

Ou, P., Huang, R. and Yao, X. (2016) 'Economic impacts of power shortage', *Sustainability*, Vol. 8, No. 7. Doi: 10.3390/su8070687.

Pasha, H.A. and Saleem, W. (2013) 'The impact and cost of power load shedding to domestic consumers', *Pakistan Development Review*, Vol. 52, No. 4I, pp.355–373. Doi: 10.30541/v52i4I.

Proskuryakova, L., Kyzyngasheva, E. and Starodubtseva, A. (2021) 'Russian electric power industry under pressure: Post-COVID scenarios and policy implications', *Smart Energy*. Doi: 10.1016/j.segy.2021.100025.

Qasim, M. and Kotani, K. (2014) 'An empirical analysis of energy shortage in Pakistan', *Asia-Pacific Development Journal*, Vol. 21, No. 1, pp.137–166. Doi: 10.18356/e84bd5d1-en.

Ruan, G. et al. (2020) 'A cross-domain approach to analyzing the short-run impact of COVID-19 on the US electricity sector', *Joule*, Vol. 4, No. 11, pp.2322–2337. Doi: 10.1016/j.joule.2020.08.017.

Salhi, R., Messaoudi, K. and Boudemagh, S.S. (2018) 'Identification of factors causing delays in construction projects in Algeria', *European Journal of Engineering and Formal Sciences*, Vol. 2, No. 1, pp.6–11. Doi: 10.2478/ejef-2018-0001.

Shobande, O.A. (2020) 'The effects of energy use on infant mortality rates in Africa', *Environmental and Sustainability Indicators*, Vol. 5. Doi: 10.1016/j.indic.2019.100015.

Stawowy, M., Rosiński, A., Paś, J. and Klimczak, T. (2021) 'Method of estimating uncertainty as a way to evaluate continuity quality of power supply in hospital devices', *Energies*, Vol. 14, No. 2. Doi: 10.3390/en14020486.

The World Bank (2018) *Combined Project Information Documents / Integrated Safeguards Datasheet (PID/ISDS)*, Additional Financing.

Tikuneh, M.A. (2018) 'Identification of system vulnerabilities in the Ethiopian electric power system', *Global Energy Interconnection*, Vol. 1, No. 3, p.8.

Ukpong, I.I. (1976) 'An analysis of causes of power shortage in Nigeria', *The Nigerian Journal of Economic and Social Studies*, Vol. 18, No. 1, pp.103–120.

Umar, B.B. and Kunda-Wamuwi, C.F. (2019) 'Socio-economic effects of load shedding on poor urban households and small business enterprises in Lusaka, Zambia', *Energy and Environment Research*, Vol. 9, No. 2. Doi: 10.5539/eer.v9n2p20.

USAID (2019) *Off-Grid Solar Market Assessment Cameroon*, USAID.

Waseem, M. and Manshadi, S.D. (2020) 'Electricity grid resilience amid various natural disasters: challenges and solutions', *Electronic Journal*, Vol. 33, No. 10. Doi: 10.1016/j.tej.2020.106864.

Wu, Y. et al. (2013) 'The impact of nurse working hours on patient safety culture: a cross-national survey including Japan, the United States and Chinese Taiwan using the hospital survey on patient safety culture', *BMC Health Services Research*, Vol. 13, No. 1. Doi: 10.1186/1472-6963-13-394.

Zahoor, H., Chan, A.P.C., Utama, W.P. and Gao, R. (2015) 'A research framework for investigating the relationship between safety climate and safety performance in the construction of multi-storey buildings in Pakistan', *Procedia Engineering*, Vol. 118, pp.581–589. Doi: 10.1016/j.proeng.2015.08.488.

Zaman, Y. (2017) 'Effects of load shedding on retail business: a glimpse from Hyderabad, Pakistan', *Grassroots*, Vol. 51, No. 1, p.13.