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Research Article

Evaluation of the Effectiveness of Existing Preventive Fire-Fighting Measures in the City of Douala, Cameroon, to Improve Decision-Making and Public Safety

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Abstract

The storage of hydrocarbons in urban areas poses significant risks to local populations, including the potential for fire, explosion, groundwater contamination, and air pollution. The objective of this study is to evaluate the efficacy of current fire prevention and suppression strategies in the city of Douala. The study will be approached by first identifying, geolocating, and characterizing urban firefighting equipment. Subsequently, a proposal will be put forth for a response system to safeguard the city in the event of a catastrophic fire at a service station. In order to achieve this objective, the current regulatory framework governing the location of FH facilities was subjected to a thorough examination. Subsequently, pivotal compliance factors were identified, operationalized, and an audit checklist was formulated. A safety questionnaire was utilized to assess the equipment within service stations. GPS technology was employed to record the GPS coordinates of the FHs. GIS10.3.1 software was utilized to evaluate the BI distribution model. The data obtained from the questionnaires were analyzed using SPSS20.0 software, which revealed that the 142 BIs studied were essentially randomly distributed across the following neighborhoods. The results of the election yielded the following results: Bonamoussadi 27 (19%), Bonandjo 19 (13%), Bali 02 (1%), Deido 09 (6%), Akwa Nord 03 (2%), Bonamoussadi 18 (12%), Makepe 18 (12%), and B. The remaining 5% is distributed among the following: Assa, Bepanda, Cité-Sic, Ndogbong, Cité des Palmiers, Bonaberi, and New-Bell. Of the 142 FH identified, 30 (21.12%) lack water, and 4 (2.81%) have a flow rate of less than 30 m^3/h with a dynamic pressure of less than 1 bar. Seventeen (11.97%) are inaccessible; 79 (55.63%) are operational; five (3.52%) are challenging to operate; and seven (4.92%) are situated within a private enclosure. The response time of the fire department is inadequate for all stations situated more than 3 km from their base in Ngondi-Douala. Only 17 (11.52%) of the stations are situated at distances of less than 5.83 km, which is conducive to efficient intervention. In contrast, 134 (88.74%) of the stations are located at distances of 5.83 km or more from the fire department base, which is not conducive to efficient intervention. The results indicate that the BIs are situated at considerable distances from the stations. Notably, the Total Laquitinie station is the sole city station with a FH located at its entrance. The database developed in this study could serve as a valuable resource for policymakers to inform appropriate action.

Keywords

Fire Hydrant, Safety, Risk, Means of Control, Urban Safety Equipment, External Defense

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1. Context

The growth of the global population and the expansion of the automotive industry are contributing to a significant increase in fuel demand. In recent years, oil companies have relocated their supply points to a greater proximity to their customers [6]. This has been done in the interest of providing local service, thereby reducing the necessity for users to travel long distances to refuel. This has resulted in the establishment of service stations in closer proximity to residential areas. The strategic planning of street furniture positioning in relation to external fire defense is essential to mitigate their effects on humans and their immediate environment [3], particularly in light of the risks faced by the city of Douala. In other words, the term "hydrant" is used to describe any hydrant that serves as a conduit for a high-flow water supply, which is used to extinguish fires. Hydrants are firefighting devices installed by local authorities for the purpose of extinguishing fires. They are comprised of an underground water network that supplies fire department fire engines. Access points are located on the pavement, either buried and accessible via a manhole, which are referred to as FH, or in the form of a post approximately one meter high, which are referred to as fire hydrants (FH) [8, 11]. These are also referred to as hydrants [2] Hydrants represent the initial line of defense in firefighting operations. It is thus imperative that they receive special attention in their design, construction, installation, and operation, in order to guarantee their continued safety and security throughout their service life. The optimal selection of a site can enhance the safety of the station and its surroundings. Conversely, a poorly chosen site can have detrimental effects on stations and their surroundings [4, 5]. It is therefore of the utmost importance to ensure that their location complies with all relevant regulatory requirements, and that they are adequately sized for fire-fighting purposes. Cameroon is experiencing a recurring phenomenon of fires in urban markets, nightclubs, and various buildings in neighborhoods with a high density of housing. In the event of an inadequate response from the fire department, the risk of fire spreading to neighboring service stations is heightened. The proximity of a hydrant to the location requiring protection has a substantial impact on the time required to respond to an incident. Furthermore, it affects the resources required by firefighting services and the efficacy of their actions [4]. In the case of a high-risk building, the requisite fire defense is provided by a first FH situated no more than 150 meters from the risk in question. In the event that the building is equipped with a dry standpipe, the FH is to be located no more than 60 meters from the dry standpipe supply connection [4]. The distance is calculated between the FH and the primary point of access to the risk in question. In contrast, the external fire defense of a special-risk building is provided by a first BI on a pressurized water network, situated a distance of 100 meters from the building's main entrance. In the case of special-risk buildings, such as service stations, fire protection is provided by a second fire hydrant situated 300 meters from the service station's main entrance. In general, FHs providing external fire defense for a hydrocarbon depot must be located at a maximum distance of 800 meters from the risk to be defended [9].

Historically, the misplacement of fire hydrants in relation to the risks they are intended to defend has resulted in a number of disasters. For instance, in 2004, the loss of over 2.3 million lives and approximately 4.5 billion dollars' worth of property was attributed to fires that could not be effectively extinguished due to the distance of fire hydrants from the affected areas. A comparable incident transpired at a liquefied gas refilling station and an adjoining service station in the Kwame Nkrumah Circle, resulting in the loss of 150 lives [6, 10]. Other authors have also identified the underlying and immediate causes of hazards at service stations, including ineffective control measures [4]. The distances and lack of pressure in BIs have been identified as contributing to the exacerbation of fires. In this context, FHs represent a crucial piece of equipment for a city's external fire defense strategy. Subsequently, several other studies have assessed the relationship between the location of hydrants and existing policies. These include studies by [1, 3, 4, 6], have posited that the absence of a city-wide drinking water network and standard safety equipment at service stations has contributed to an increased incidence of fire-related disasters. The global oil industry is confronted with the challenge of balancing the critical need for energy supply with the imperative of ensuring safe and sustainable operations. The optimal selection of sites for these industries, along with the implementation of urban fire protection measures, has the potential to mitigate these challenges.

The analysis of the suitability of station location and FH has concentrated on the significance of GIS-based analysis, as evidenced by the work of Aneziris [5, 6], or MCDA and GIS [1, 3, 12]. These tools are invaluable for addressing issues in a spatial context, as they facilitate the evaluation and weighting of different decision variables in accordance with their relative importance in reaching an optimal decision. The application of MCDA to the siting of stations and FHs has demonstrated that the absence of FHs is a contributing factor in the aggravation and spread of fires. The occurrence of major human and material disasters in the vicinity of service stations has been widely attributed to the absence of firewalls in service stations [3], which represents a negative safety aspect [4]. At the beginning of the 20th century, the African continent experienced a rapid process of urbanization, largely driven by a high birth rate. In particular, the cities of Central Africa failed to adapt their infrastructure and management structures to the new urban realities, a failure that was characteristic of many cities in the region. In Cameroon, Douala's status as the country's economic capital and the heart of Central Africa attracts numerous oil companies, who view it as an important market for their products. The city of Douala has approximately 152 service stations in operation where liquid and gaseous hydrocarbons are stored. However, these facilities lack the requisite fire-fighting resources. Such deficiencies can potentially result in catastrophic fires [7, 10]. A total of 142 hydrants have been identified within the entire city of Douala, which encompasses an area of 410 km². Some of the identified hydrants are inoperable due to a lack of water flow or pressure. In addition, other hydrants have simply been laid outside or inside private gates. Furthermore, some shopkeepers' kiosks are installed above the FHs, making them impossible to find in the event of fire. Consequently, the risk of major fires in Douala is more complex than the problem of an ineffective operational response, the non-availability, lack of water coverage, and difficult access to external fire-fighting resources.

In Order No 01/98 from MINMEE on January 05, 1998, the government establishes the conditions for the establishment of petroleum product distribution stations. Article 5 stipulates that service stations must comply with the following requirements: the presence of a BI in the event that a public drinking water distribution network is in place; the availability of appropriate means for combating hydrocarbon fires; and the incorporation of a firewall constructed in accordance with the prevailing regulatory standards. In its most basic form, urban planning should give priority to the installation of FHs in densely populated areas in close proximity to hazardous materials infrastructures and their associated transport routes. The construction of FHs in buffer zones serves to reduce exposure to hazards associated with explosive atmospheres [2, 4]. In light of the inherent risks associated with service stations, it is of paramount importance that the safety measures outlined in local standards are fully implemented. However, the legal framework governing the siting of petroleum product distribution stations is often poorly integrated into land-use planning, particularly with regard to the selection of sites for the construction of drinking water networks for BIs. In this context, the present study was carried out to examine the spatial distribution of BIs and public safety in the municipality of Douala, Cameroon. The analysis was justified by the fact that no data on this aspect of research in the city has been published to date.

2. Materials and Methods

2.1. Samples

The initial step was to identify all firefighting resources available in the city of Douala. Two samples were utilized to evaluate the existing firefighting resources in Douala. The initial sample pertains to resources external to service stations, encompassing firefighters' response time, the availability and functionality of fire hydrants, and other pertinent factors. The second sample focuses on resources within service stations, including the firewall, extinguishers, sandboxes, and the network of fire hydrants (RIA), sprinkler network, automatic fire detectors, high-expansion foam automatic extinguishing system, horn, safety register, and training.

2.2. Data Collection

The data collection process was conducted over the course of two months, from January to February 2021. Information regarding fire safety equipment was gathered through the administration of a questionnaire, the completion of an FDS (safety sheet), the conduct of a risk assessment, and the performance of inspections. These methods were employed at all service stations [6]. Information pertaining to BIs and fire safety equipment at service stations was gathered. A number of photographs were taken of BIs. The geographical coordinates of all sampled fire hydrants were recorded, along with the name of the district in which the hydrant is located and a distinctive landmark. The locations of fire hydrants were recorded using global positioning system (GPS) receivers, with the geographic coordinates displayed digitally. Additional data were procured from online sources, including ISI Web of Science and Google Scholar. In the second phase of the study, the distances between the BIs and the nearest service stations were evaluated. Subsequently, control factors, including the distance between the FH and the nearest service station, FH functionality, FH performance, and availability, were evaluated. In the second stage of the study, the fire hydrants were grouped into 14 zones, as follows: Zone Akwa, Zone Bali, Zone Bonamoussadi, Zone Bonanjo, Zone Bonapriso, Zone Deido, Zone Akwa Nord, Zone Bepanda, Zone New Bell, Zone Cité des Palmiers, Zone Ndogbong, Zone Cité Sic, Zone Bassa, and Zone Bonaberi.

2.3. Data Analysis

The data obtained from the questionnaires were analyzed using the statistical software package SPSS 20.0. Descriptive and inferential statistical techniques were employed. The data obtained from this study were analyzed using the PRA (Primary Risk Analysis) method. In particular, the risk criticality table was employed to evaluate the criticality of the risk in the absence and presence of existing control measures. The data obtained from the questionnaire were analyzed using the SPSS 20.0 software. Descriptive and inferential statistical techniques were employed. The nearest neighbor analysis [2, 5] utilising the Euclidean distance metric, was employed to ascertain the spatial distribution of BI within the GIS 10.3.1 environment, and to provide a description of their distribution (Rn). The GIS V.10.4 software facilitated the entry of GPS coordinates for all BIs in the city of Douala, thereby providing a comprehensive ground plan of the existing control circuit.

The algorithm employs a distance-based approach to determine the distribution pattern of BIs, which can be classified as random, normal, or clustered. The algorithm provides researchers with a numerical value for the clustering of a geographical phenomenon, thus enabling them to contrast it more accurately with other locations. A brainstorming session was conducted with stakeholders from the service station industry to identify and collate as much safety-related information as possible. This was done collectively and without any restrictions. The participants were permitted to generate their own concepts and complete the safety checklists at their own discretion, without being subjected to any prior evaluation or judgment. This tool was employed as an additional resource in conjunction with the 5P method to facilitate the identification of the underlying causes of the primary deficiencies observed in this sector, specifically in relation to service station management stakeholders. These shortcomings are attributable to a number of factors. The aforementioned factors are identified through the application of the 5P method. The 5P method is based on a systematic inquiry into the underlying causes of a phenomenon through the use of five fundamental "why" questions. The objective of this line of inquiry is to ascertain the fundamental cause of the problem. The data obtained from this study was analyzed using RPA. In particular, the RPA tool was used to assess the effectiveness of control measures, identify hazard situations, evaluate risk elements, and assess the criticality of target points both with and without control measures. Additionally, the tool integrated other aspects, including causes, consequences, existing measures, and proposed measures. Finally, the tool enabled us to assess whether the risk could be considered acceptable. The assessment was conducted in three stages (Figure 1).

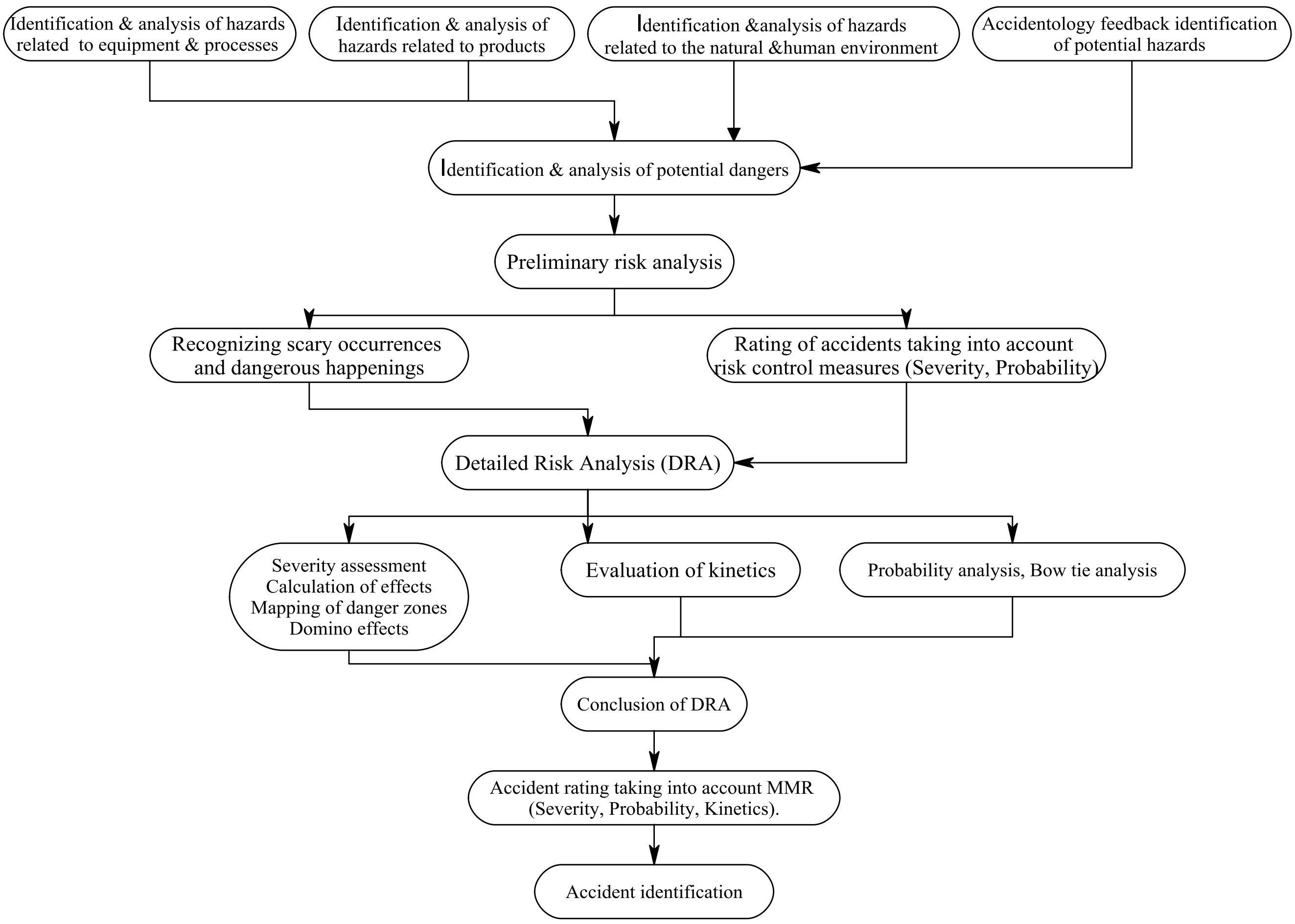

Figure 1. *Risk identification.*

Following the identification of the risks, three rating grids were defined: the criticality grid, the probability grid, and the severity grid. The QQOQCCP method was employed to facilitate the implementation of the proposed actions by the relevant authorities, with the objective of reducing the risks to which the populations of the city of Douala are exposed. This tool was developed based on a systematic approach to safety checks at service stations in Douala [6]. The aforementioned tool enabled us to consider all aspects of the safety audit conducted at service stations. It proved instrumental in facilitating the implementation of the proposed actions, as it incorporates the objectives of the measures, the parties responsible for their implementation, the timeline, and the stakeholders involved. Table 1 below provides a summary of its application in this study.

Table 1. *Illustrates the application of the QQOQCCP tool.*

What is it?	Who is in charge?	Where is it?	When is it implemented?	How should it be implemented?	How many people are affected?	Why is this being done?
What is the action to be taken?	Who is responsible for its implementation?	Where is this implementation taking place?	When is it implemented?	How should it be implemented?	How many people are affected?	Why is this being done?

3. Results and Discussions

3.1. Spatial Distribution of Hydrants in the City of Douala

A total of 142 IBs were distributed across the town's various neighbourhoods at the time of the study. The majority of these IBs, 27 (19%), are located in Bonamoussadi, 19 (13%) in Bonanjo, 9 (6%) in Bali, 9 (6%) in Deido, 3 (2%) in Akwa-Nord, 18 (12%) in Bonamoussadi, and 18 (1%) in other areas. Additionally, 2% are situated in Makepe, 5% in Bassa, 5% in Bepanda, 3% in Cité-Sic, 0.7% in Ndogbong, 2% in Cité des Palmiers, 7% in Bonaberi and 4% in New Bel.

It is evident that a number of BIs lack the requisite water and pressure levels to be operational. It is also noteworthy that a number of the FHs are not currently operational, which presents a significant safety hazard. Of the 142 FHs identified and sampled in the six districts of the city of Douala, 30 (21, 12%) lack water, four (2, 81%) have a flow rate of much less than 30 m^3/h and a dynamic pressure of less than 1 bar. The minimum pressure required for a fire hydrant to function normally is 17 (11.97%), which are unavailable. 89 (62.67%) are operational, 1 (0.7%) is difficult to operate, and 1 (0.7%) is located within a private fence. Some are even inaccessible due to being covered in concrete. The current situation regarding the risks associated with water supply operations in the BIs installed or with their unavailability in different areas of the city of Douala is presented in Figures 1-9 below. The images presented in these figure below illustrate the deplorable state of disrepair and neglect of the hydrants, which raises significant concerns about their operational readiness and ability to safeguard the city of Douala in the event of a fire.

Figure 2. *Fire hydrant blocked by mudslides and debris from a gully.*

Figure 3. *Fire hydrant blocked by mudslides and debris from a gully.*

Figure 4. Fire hydrant not operational.

Figure 5. Fire hydrant below a shop kiosk.

Figure 6. Fire hydrant (PI) inside a private barrier.

Figure 7. Fire hydrant blocked by undergrowth and sand.

Figure 8. Cement-sealed hydrant.

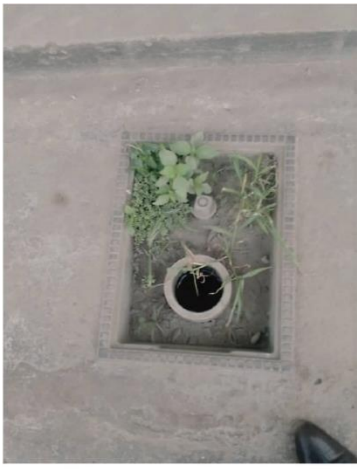

Figure 9. Fire hydrant unavailable.

The locations of the 142 hydrants, 152 service stations and the main fire brigade base identified in the city of Douala are illustrated in the figures below (10 to 16).

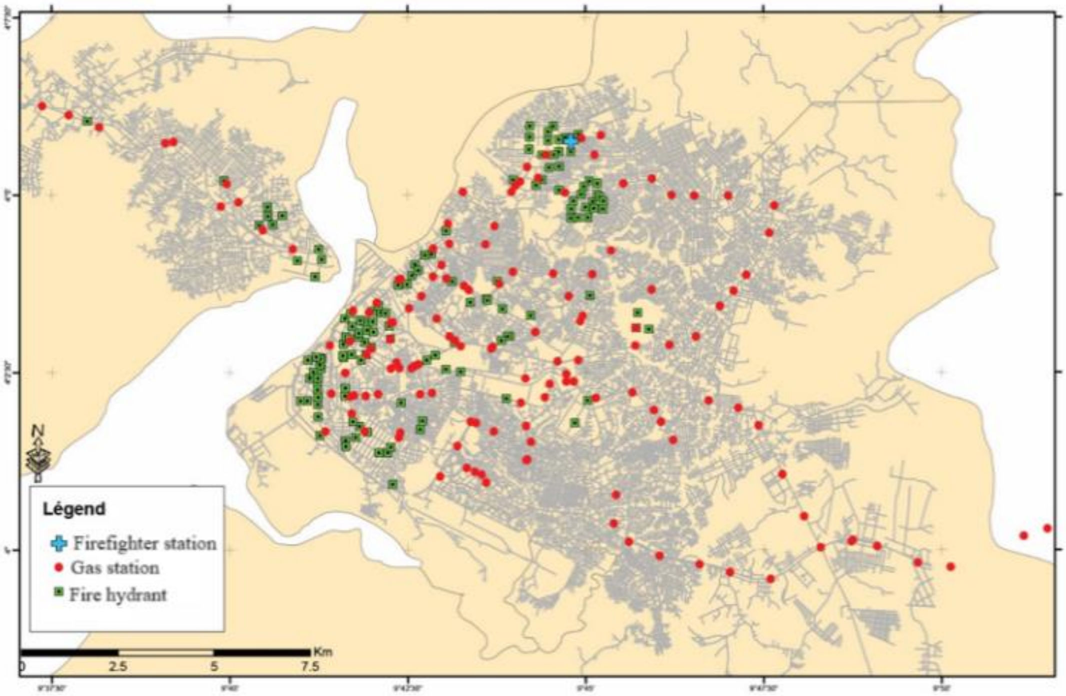

Figure 10. *Hydrants, service stations and fire brigade base in the city of Douala.*

Figure 11 illustrates that the I arrondissement of Douala has 60 hydrants distributed across its various neighbourhoods, representing 42.25% of the total number of hydrants in the city. Additionally, there are 36 service stations in the I arrondissement, accounting for 23.36% of the total number of service stations in Douala.

Figure 12 depicts that the II arrondissement of Douala has 5 hydrants and 11 service stations, representing 3.52% and 7.23% of the total number of hydrants and service stations in the city, respectively.

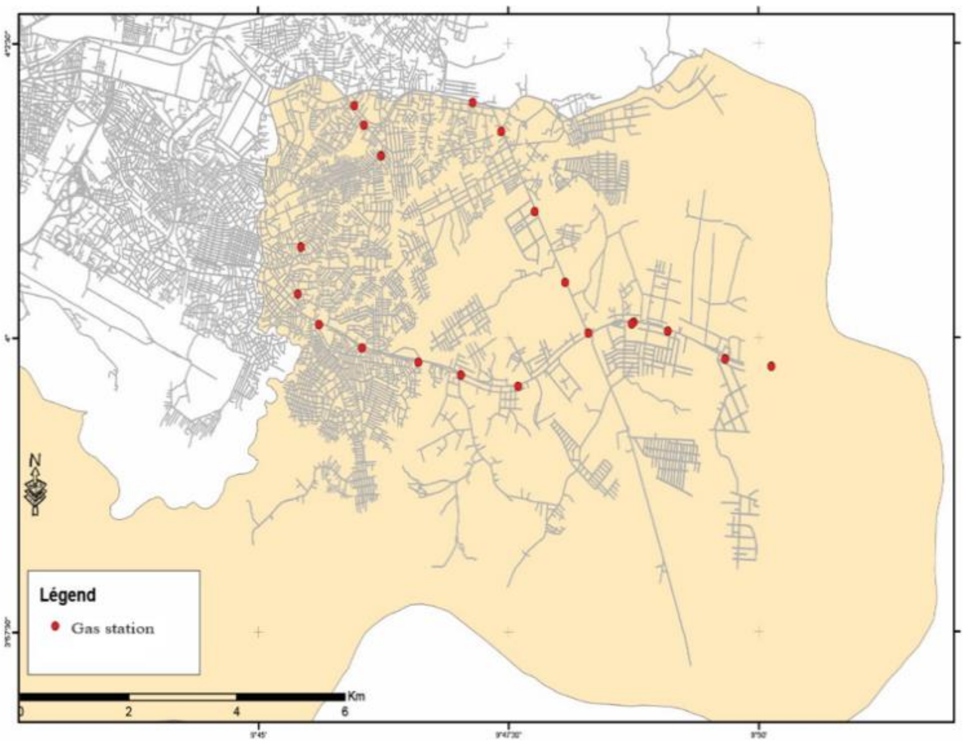

Figure 11. *Hydrants and service stations in the Douala II district.*

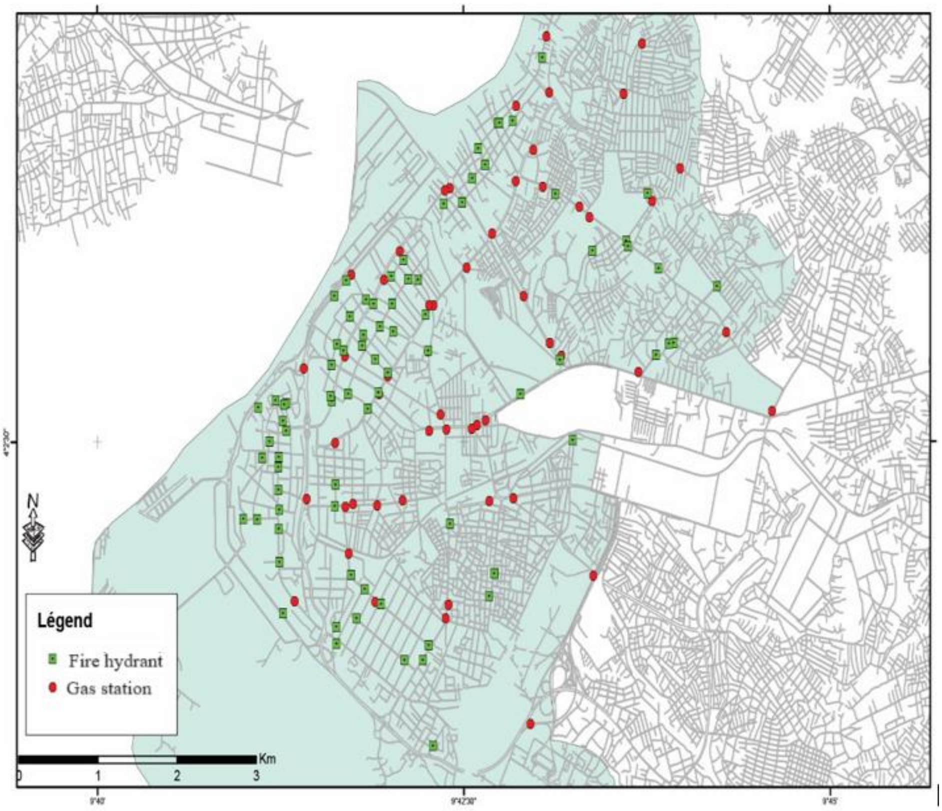

Figure 12. *Hydrants and service stations in the Douala I district.*

Figures 13 and 14 illustrates that the Douala III arrondissement has 17 hydrants distributed across various neighbourhoods, representing 11.97% of the total. Additionally, there are 72 service stations, accounting for 47.36% of the total.

Similarly, Figure 13 depicts that the Douala IV arrondissement has 11 hydrants situated in different neighbourhoods, representing 7.74% of the total. Furthermore, there are 14 service stations, accounting for 9.21% of the total.

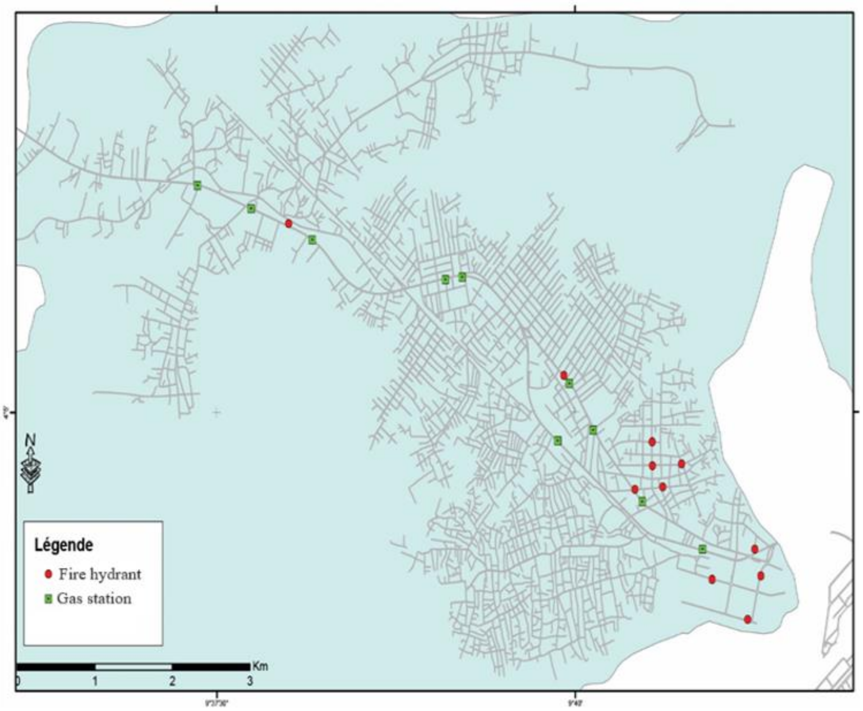

Figure 13. *Hydrants and service stations in the Douala III district.*

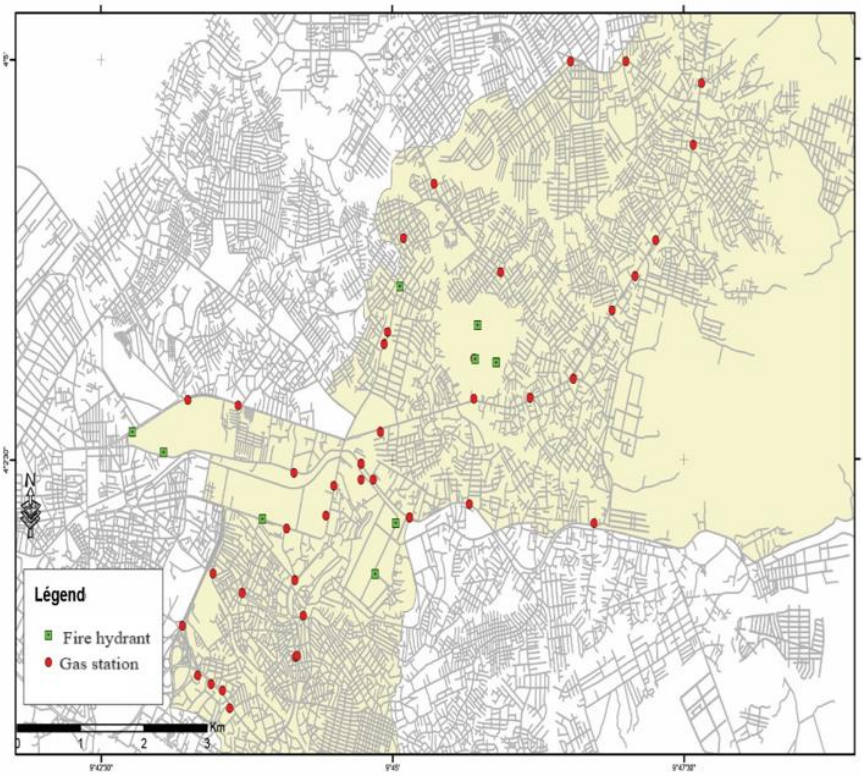

Figure 14. *Hydrants and service stations in the Douala III district.*

Figure 15 illustrates that there are 49 (34.50%) hydrants in the various districts of Douala V, along with 19 (12.5%) service stations.

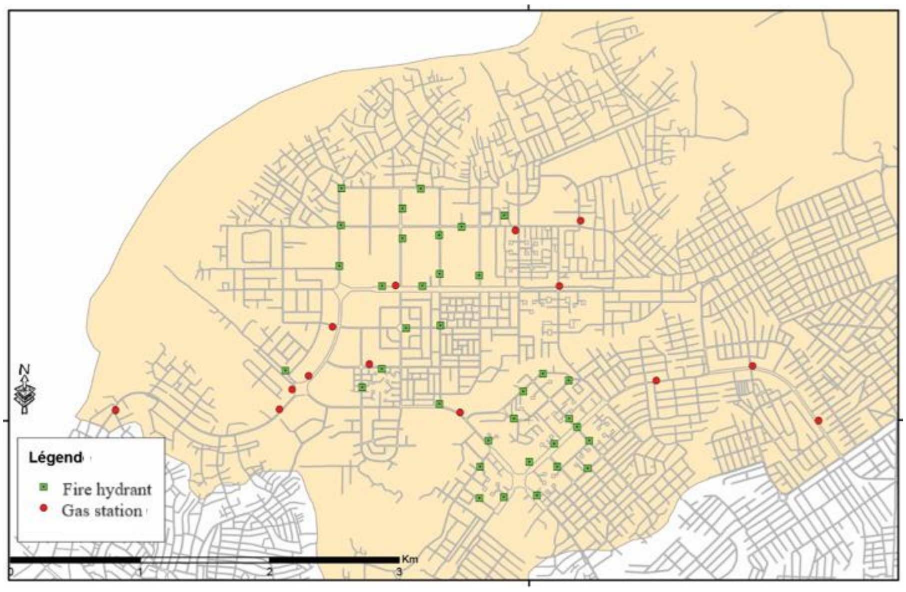

Figure 15. *Hydrants and service stations in the Douala V district.*

3.2. Distribution of Fire Hydrants in Douala

The spatial distribution of hydrants by district is illustrated in Figure 16 below. It should be noted that several areas of the city are not included in this map as they are not equipped with hydrants.

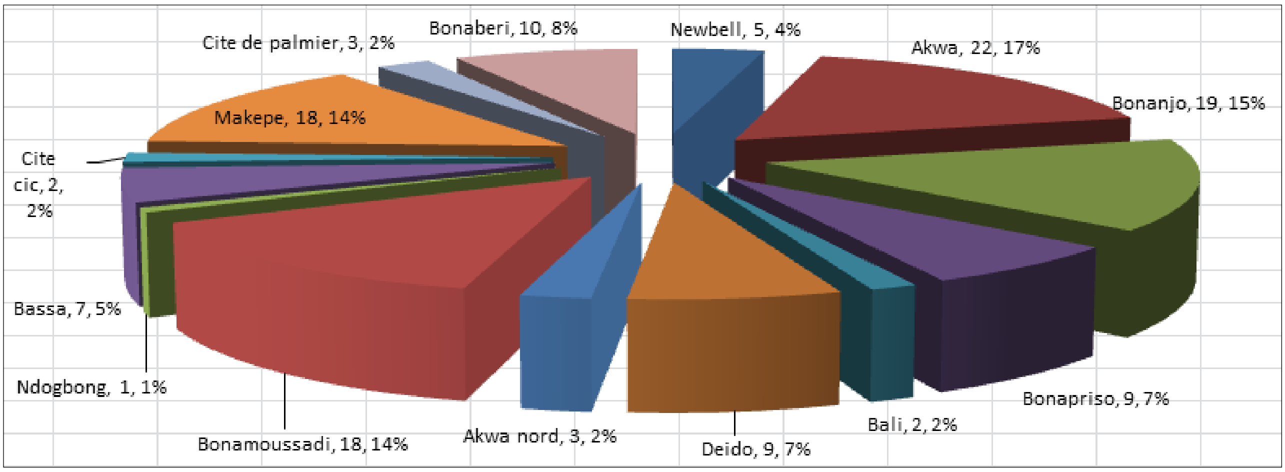

Figure 16. *Distribution of fire hydrants in Douala.*

The arrondissement of Douala IIe, with an area of 16km², a population of 1,020,061 and 11 service stations, is devoid of both a FH (Figure 13). This is a cause for significant concern in the event of a fire, given that the fire brigade base is located over three kilometres away. The second phase of the study entailed an assessment of the functionality of the existing fire-fighting resources in the city of Douala. A number of criteria were taken into consideration, including water supply, unavailability, water pressure, manoeuvrability and positioning in relation to the service stations. The second sample focused on the resources located within the service stations, encompassing the firewall, fire extinguishers, sand pits, RIA network, sprinkler network, automatic fire detectors, high-expansion foam automatic extinguishing system, horn, safety register and training.

3.3. Existing Means of Control

3.3.1. Means of Control Outside the Stations

The city of Douala is home to a substantial fire brigade base, situated within the Ngondi district. Additionally, two auxiliary bases are located in the city: one for the navy, situated at the Youpwe naval base, and the other at the airport. The fire brigade bases are situated at considerable distances from one another, with considerable distances also separating them from the service stations. Of the 152 service stations identified in the city of Douala, 135 (88.81%) are situated at distances exceeding 5.83 km from the fire brigade bases. This distance precludes the possibility of effective intervention within the time limits following the declaration of a fire. The 135 stations in question are illustrated in Appendix 8. Table 2 illustrates that 17 (11.18%) service stations are situated at distances of less than 5.83 km, which is conducive to intervention within the stipulated time limits. Furthermore, the poor state of the roads in the city of Douala serves to further restrict the effectiveness of the fire brigade's intervention. Any service station located more than 3km from the fire brigade bases in the city of Douala is rendered inaccessible. The optimal intervention distance is estimated in equation (1) below:

$$d = v_m * t_{max} \quad (1)$$

With:
v_m= 50 km/h: average speed in town
t_{max}= 7 mn: maximum response time

Table 2. *Service stations located at distances of less than 5.83 km.*

ID	Service stations
1	Total Rond Point Deido 1
2	Total Rond Point Deido 2
3	MRS Douala Bar
4	MRS Ngodi
5	MRS Valée Bessengue
6	Total Hotel le Ndé
7	MRS Hotel le Ndé
8	Total Jamot
9	Total Foch
10	Total Laquintinie
11	Total Ngodi Camp Yabassi 1
12	Total Ngodi Camp Yabassi 2
13	MRS Camp Yabassi
14	Ola Energy Bonakouamouang
15	Total Reunification
16	MRS Akwa Palace
17	MRS Douche Akwa

3.3.2. Functionality of Control Systems Outside Service Stations

The functional testing of all the FHs was conducted with the assistance of two fire brigade officers. The FHs in the city of Douala are supplied by a public water supply network under pressure, albeit with some instability in the water supply. This results in 30 (21, 12%) of the FHs in the city of Douala being rendered ineffective. The results of the functionality tests are presented in Figure 18 below. They show that of the 142 hydrants identified, 18 (12.67%) are unavailable, 89 (62.67%) are operational, 30 (21.12%) lack water, 4 (2.81%) lack pressure and 1 (0.70%) is difficult to operate.

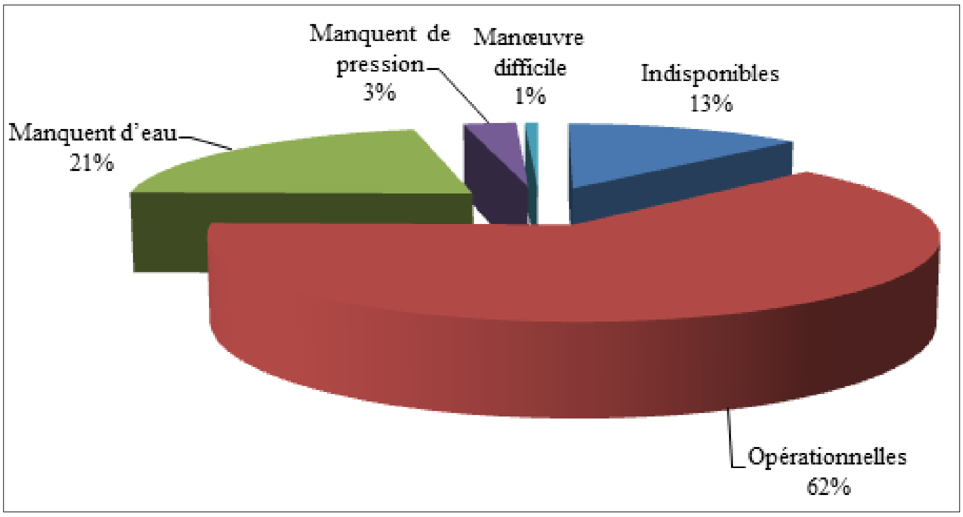

Figure 17. *Functionality of fire hydrants in Douala.*

3.3.3. Distances Between Hydrants and the Nearest Service Stations

Of the fire hydrants identified, 108 (76.05%) are situated at a distance of more than 2,000 metres from the nearest service station, while 21 (14.78%) are located at a distance of less than or equal to 400 metres from the nearest service station. The distance from the fire station is equivalent to the length of the fire brigade hoses, and 13 (9.15%) are situated between 400 and 500 metres from the nearest service station (Figure 18).

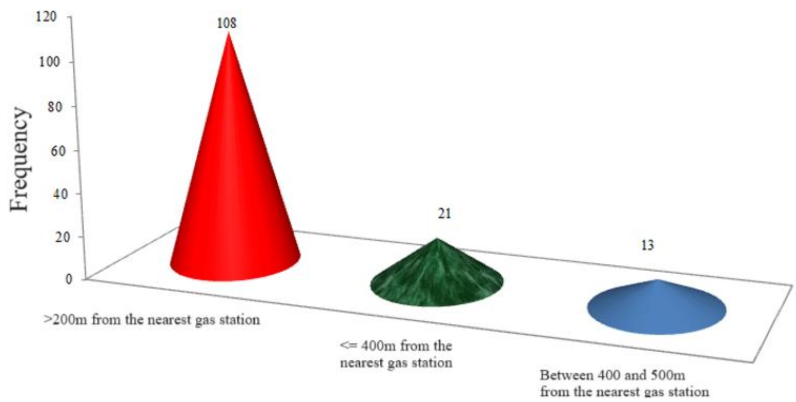

Figure 18. *Positioning of hydrants in relation to service stations.*

3.3.4. Means of Control Within the Stations

A total of 62 (40.78%) service stations were found to have 10 ABC and CO_2 fire extinguishers, with a minimum operating time of 12 seconds for each appliance. Additionally, 109 (71.71%) service stations were observed to have a single sandbox instead of four, while 57 (40.14%) did not have a network of fire hose reels (FHR). Among the 43 service stations with a network of FHR, Thirteen service stations have functional booster pumps; 152 (100%) do not have fixed sprinkler systems or high-expansion foam systems; five (3.28%) have audible gas alarms in storage compartments; 43 (11.18%) have a safety register; and only 17 (11.18%) have staff trained in fire safety.

3.4. Assessing the Effectiveness of Existing Resources

The third phase of the study involved the assessment of the criticality of fire control resources in the city of Douala. In order to evaluate the safety of these resources, a methodology based on risk, threat, impact and vulnerability was employed. The risk associated with each resource was calculated as the product of the probability of the threat, the impact and the vulnerability. This approach enabled the generation of a matrix grid in terms of threat and impact, which is presented in Table 3.

Table 3. *Matrix grid.*

Impact	**Threat**					
	Very unlikely	**Unlikely**	**Remote**	**Casual**	**Likely**	**Very likely**
Minor	Very low	Very low	Low	Low	Moderate	Moderate
Moderate	Very low	Low	Moderate	Moderate	Moderate	Moderate
Severe	Low	Moderate	Moderate	Strong	Strong	Strong
Major	Low	Moderate	Strong	Strong	Severe	Severe
Critical	Low	Moderate	Strong	Severe	Severe	Critical
Disastrous	Moderate	Moderate	Strong	Severe	Critical	Critical

The term "very low risk" is used to describe a situation in which the risk in question has been reduced to the lowest reasonable level. The summary enables the probability of the risk occurring to be assessed, thus facilitating the establishment and prioritisation of preventive measures designed to reduce the risk in question. It is inherent to the nature of service stations and the geographical area in which they are situated that they are susceptible to a number of vulnerabilities. Such vulnerabilities can be effectively managed through the implementation of appropriate control measures. The level of risk may be increased depending on the operational control measures in place at the service station and the extent of its operating area. The data analysis is presented in tabular form, with a summary of the human, material and environmental issues identified within the study area. Table 4 also sets out the measures adopted in the study area and the reasons for choosing these measures to reduce the vulnerability of the human issues identified and to control future urban development. It summarises the possible threat scenarios for service station operations within a radius of less than 100 m from dwellings.

Table 4. *Summary of human, material and environmental issues identified in the study area.*

Operations	**Risks**	**Criticality**		**Risk assessment before implementing preventive measures**	**Means of control**	**Risk assessment following the implementation of preventive measures**
		Potential impact				
Storage of hydrocarbons	Fire	Minor	Moderate	Moderate	Fire extinguishers	Stockings
Storage of hydrocarbons	Fire	Minor	Moderate	Moderate	Sand traps	Low
Storage of hydrocarbons	Fire	Minor	Moderate	Moderate	RIA	Low
Storage of hydrocarbons	Fire	Minor	Moderate	Moderate	Sprinkler	Very low

Operations	Risks	Criticality		Risk assessment before implementing preventive measures	Means of control	Risk assessment following the implementation of preventive measures
		Potential impact				
Storage of hydrocarbons	Fire	Minor	Moderate	Moderate	Automatic fire detectors	Very Low
Storage of hydrocarbons	Fire	Minor	Moderate	Moderate	Fire separation wall	Very Low
Storage of hydrocarbons	Fire	Minor	Moderate	Moderate	High-expansion foam automatic extinguishing system	Very Low
Storage of hydrocarbons	Fire	Reviews	Severe	Severe	Fire extinguishers	Severe
Storage of hydrocarbons	Fire	Critical	Severe	Severe	Sand trays	Severe
Storage of hydrocarbons	Fire	Critical	Severe	Severe	Fire hydrants	Severe
Storage of hydrocarbons	Fire	Critical	Severe	Severe	RIA	Severe
Storage of hydrocarbons	Fire	Critical	Severe	Severe	Sprinkler	Severe
Storage of hydrocarbons	Fire	Review	Severe	Severe	Automatic fire detectors	Severe
Storage of hydrocarbons	Fire	Review	Severe	Severe	Fire separation wall	Severe
Storage of hydrocarbons	Fire	Critical	Severe	Severe	Automatic high-expansion foam extinguishing system	Severe
Storage of hydrocarbons	Explosion	Disastrous	Review	Critical	Fire extinguishers	Review
Storage of hydrocarbons	Explosion	Disastrous	Critical	Critical	Sand trays	Critical
Storage of hydrocarbons	Explosion	Disastrous	Critical	Critical	Fire hydrants	Critical
Storage of hydrocarbons	Explosion	Disastrous	Critical	Critical	RIA	Critical
Storage of hydrocarbons	Explosion	Disastrous	Critical	Critical	Sprinklers	Critical
Storage of hydrocarbons	Explosion	Disastrous	Review	Critical	Automatic fire detectors	Review
Storage of hydrocarbons	Explosion	Disastrous	Review	Critical	Fire separation wall	Review

The fourth phase comprised an evaluation of the efficacy of the fire control measures deployed in the city of Douala prior to the implementation of preventative measures, as well as an investigation into the efficacy of the aforementioned preventative measures. The effectiveness of the safety measures implemented at service stations in the event of a fire was evaluated. The summary table indicates a threat level ranging from moderate to low or very low. The results demonstrate that, in the event of a significant fire or an explosion followed by a fire, operators have established certain safety measures. However, despite these measures, the risk remains considerable. This could be attributed to the absence or inadequacy of existing control measures or the lack of employee training.

4. Conclusions

The public water supply network in the city of Douala is insufficient to provide a uniform flow to each appliance with a flow rate of less than 30 m^3/h. It is unable to provide a simultaneous flow to multiple FHs, with the level of risk determining the number that can be supplied at any given time. The town's hydraulic capacity is inadequate for effectively combating a significant hydrocarbon fire. Of the 142 FHs identified, 114 (80.28%) are situated at a considerable distance from the service stations for which they are responsible for protecting. It is notable that none of the service stations in Douala are equipped with sprinklers or firewalls. This indicates that the risk of fire remains high, despite the safety measures that have been implemented by the government and operators. The remoteness of the fire brigade base from the target points to be protected, coupled with the poor condition of the roads leading to these target points, serves to further exacerbate the operational inefficiency of these control measures. The findings of this study indicate a significant cause for concern, demonstrating that the proximity of service stations represents a considerable risk to neighbouring residential properties. The findings of this study indicate that the probability of extensive fire outbreaks in the city of Douala is a tangible concern. It is evident that the occurrence of a fire at a service station situated within a residential area would inevitably result in extensive damage and loss of life. In such an event, it would be necessary to consider the expropriation of both the service stations and the surrounding residential properties, on the grounds of public interest. This expropriation would serve to reduce the perimeter of exposure of the population to the risk of fire in the city of Douala.

Abbreviations

GPS	Global Positioning System
SPSS	Statistical Package for the Social Sciences
GIS	Geographic Information System
FH	Fire Hydrants
MINMEE	The Ministry of Water and Energy Is the Governmental Department Responsible for the Management of the Country's Water Resources and Energy Production
CO_2	Carbon Dioxide
RPA	Robotic Process Automation
FHR	Facility Health Records
RIA	Regulatory Impact Assessment
AHP	Analytic Hierarchy Process
TOPSIS	Technique for Order of Preference by Similarity to Ideal Solution
MCDA	Multi-Criteria Decision Analysis

Author Contributions

Batambock Samuel: Conceptualization, Formal Analysis, Investigation, Project administration, Software, Validation, Visualization, Writing – original draft, Supervision, Writing – review & editing

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Data Availability Statement

The data employed in the study was procured directly from the firefighting apparatus (FH) situated within the city of Douala. The data encompassed information pertaining to the geographical positioning of the apparatus, its operational status, and its distribution across the city. The data was obtained through the administration of safety questionnaires, field observations, and the utilisation of GPS and GIS technologies.

Conflicts of Interest

The authors declare no conflicts of interest.

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Biography

Batambock Samuel is a permanent lecturer at the University of Douala, in the National Higher Polytechnic School of Douala, in the Department of Marine Engineering and Industrial Fishing. He is in possession of a Professional Industrial and Commercial Fishing Captain's Certificate, which he obtained in Russia in 1995. He is an expert in maritime security and has obtained several certifications, including ISPS Port and ISPS Ship certificates in France in 2015, as well as PFSO/ASIP certification in Nice in 2016. In 2013, he obtained the STCW certificate in teaching and management of maritime schools in Spain. Furthermore, in 2008, he participated in a training course on the construction of professional training programmes as part of a collaboration between France and Cameroon.

Research Field

Batambock Samuel: Maritime engineering, Industrial fishing, Maritime safety, ISPS code compliance, Port security, Ship security, Maritime education, Vocational training programs, Fisheries management, Sustainable fishing practices.