Analysis of the Fire Risk as a Tool of Decision-Making Aid for Problems of Planning in the City of Yaounde

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Abstract: The life space of populations is materialized by the habitat. This habitat spreads with the population increase. In the urban area, the transformation of the habitat is sometimes accompanied by problems like, segregation, risks.., raising the problem of the zone planning. The case of fire risk in the city of Yaounde is mentioned here and calls for an analysis, in a context that clarifies on decision making for problems of zone planning.

The strategy of approach here is to determine steps of phenomenon analysis, to describe the fire risk in its evolution while unveiling the derived information, which can characterize the urban area; an application is made to the city of Yaounde.

At the end of this survey, the elements of definition and characterisation of the fire risk in urban area follow by characteristics of the city zones of Yaounde, taking account fire risk and measures to remedy them have been done.

Keywords: Urban area, zone planning, fire risk, elements of fire risk, characteristics of the fire risk, characteristics of zones.

1. INTRODUCTION

The urban area ensures to populations several functions including sanitary, social, administrative, etc.. Difficulties of management increase with the expansion of the city. Those of developing countries are the main concerned. These management difficulties become more pronounced with the appearance of several problems (poverty, segregation, risk, etc.). Thinking about solutions, it would firstly be necessary, to provide knowledge concerning them. It is the case of fire risks in the city of Yaounde of which we propose to study the complexity of existence in order to provide information of decision-making for problems of urban planning.

There is a relationship between fire risk and the elements of habitat; what strategy of risk analysis is necessary so as, to provide information of solution to the problem of zone planning?

For that, we have counted all elements of existence of fire risk in their space while following its setting up since the appearance until the occurrence of the fire catastrophe [1]. We also propose to the relations and properties between these elements. This numbering leads to the determination of natures, and possible types of entities. This description of existence of fire risk in its environment permits to discover factors of risk [2], including mainly elements of habitat, and to characterize zones and constructions concerned. Looking forward to eliminate these factors, we have proposed solutions to the planning of zones.

This work is structured as follows:

-Introduction

- Materials and methodology
- Results
- Conclusion and discussion

2. MATERIALS AND METHODOLOGY

2.1. Materials

A certain number of basic elements are necessary for the survey:

a). Factors, Showing the Presence and the Scope of the Problem

- the fire history in the concerned zones must be evoked;
- causes of apparition of fire risk must also be established;

b). Elements of Existence of the Fire Risk in the Urban Area

Fire risk can be defined as the combination of the probability of occurrence of a fire catastrophe, with intensity of its consequence (vulnerability) [3].

The fire risk is a phenomenon whose evolution occurs, by the progressive setting up of its elements in a space of habitat:

Fire Risk Related Terminology: factors of fire risk appearance, scope fire universe, urban data, flame sources, stakes, risks, movements, preventions, probability, bursting flames, precautions, elements state profiles of fire risk, mapping identity of the fire risk, quantitative identity, assessment of the fire risk, occurrence of catastrophe, conditions of propagation, urban area.

c). Tools of Data Processing

Data and statistics will be used for processing numerical and probability will serve to characterize the state of the fire risk. The urban data on the habitat of the city concerned

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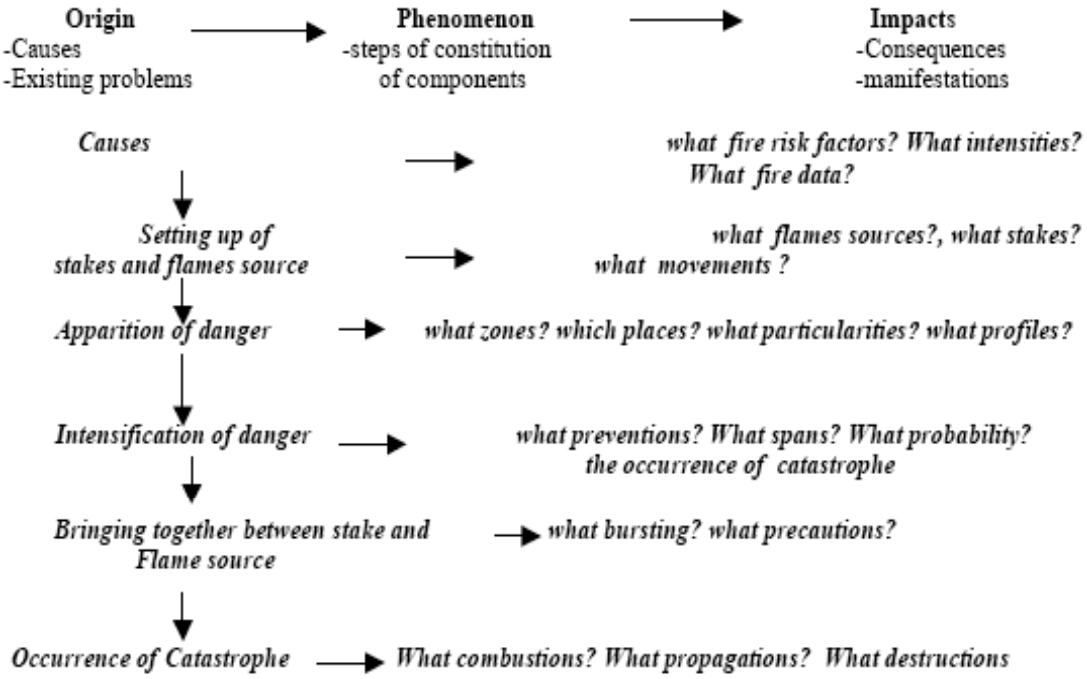


(types; buildings materials, spatial management, accessibility, urban technical networks, daily activities) are necessary for the knowledge of the urban area.

2.2. Methodology

The analysis or study of the existence of the fire risk and the characterisation of the concerned zones consists to:

- show the problem of fire risk: the events related to the phenomenon of the fire risk in an environment have been studied, in order to determine its characteristics including element of definition, identity, measure, occurrence of the disaster and explanatory factors;
- to characterize the different types of habitat that form the urban area, using elements of definition and characteristics of the fire risk.

ELEMENTS OF DEFINITION AND FIRE RISK CHARACTERISTICS

To show the problem, the following items have been considered: the **occurred fire catastrophe**, reasons or **factors of the fire risk** appearance, (specifying their zone) in the concerned urban area.

The evolution of the phenomenon through the **scope fire universe** has been presented.

Elements of Definition of Fire Risk

There numerous elements :flammable materials or flames source products, stakes, distances between stake and flammable source, hazard, types of zone, profiles of state of elements, type of fire risk, flame bursting, propagation

Once in the phenomenon, the flammable materials that indicates all the generic elements of the fire shall be itemized

Flames sources have been counted, by the identification of everything that produces the flames.

Stakes are determined, by a classification that gives it a characteristic particular meaning (nature, role, function), knowing the flammables materials. These stakes are associated to the concerned zones at the same time.

Distances have also been listed while considering all cases of position of the flame source, in relation to the stake.

Movements evolving toward contact have been determined. An applied movement between flame source and stake drives to fire risk.

To get the **risk**, we apply the movement to a source flame.

Status Profiles of Elements

The knowledge of the different elements combinations is indispensable to the determination of the fire risk in a point of bursting flame. It has been obtained while studying all different cases of evolution of the system (stake, flame source, catalyst, distance) to characterise propagation zones.

Types of Zones and Size

The function of existence of the stake in a zone leads to zones of risks.

The urban area is constituted by a set of habitats which shall be characterized based on the elements of fire risks. The urban area is characterised by: the function of the zone, the nature of the existing stake, the presence flame sources.

The different types of existing habitat in centre urban and interfacing have been isolated.

An analysis shows that theses zones are not homogeneous; there exists a disparity at the level of the stake distribution. The distinction between them requires to use their function and their role. In the distinction of zone, the following have been considered:

- the point of flame bursting with its neighbourhood, a reduced zone either extended, the whole urban area.

Possibilities of Flame Bursting

The existence of the fire risk depends on the presence of stakes, except for the case of burned rejected material. Fire burns mainly in the presence of the stake and therefore, deal birth directly to the fire. There exist many possibilities of flame bursting; we get them while growing stakes and sources flames.

Point of Flame Bursting

The **different types of flame bursting** are obtained by the combination of generic element which burst with product flame element at a distance d, plus movement.

Propagation

The **propagation** is determined by a set of fire catalysers**.** There is a disparity at the level of the stake distribution. To distinguish between them, their function and their role have been used. This distinction is based on the propagation that exists in the zone.

Characteristics of Fire Risk and Zones

The main characteristics include: type of danger, type of fire risk, quantitative identity, qualitative identity, mapping identity, measure, impacts (manifestations and occurrence).

Type s of Danger

Fire risk dangers are provided from the composition of elements **of scope fire universe.**

Types of Fire Risk

The **type of fire risk** is gotten by indicating the relationship with its expression, the nature of the stake, its measurement, size of the place (point of flame bursting with its neighbourhood, group of building, zones, and urban area).

All danger in the whole zones in the city can be counted and their presence can be changed. Thus, to consider a probability of its presence somewhere and also a probability to take in account dominating danger are possible.

Identities of Fire Risk

- for a reduced zone as a room or local, a building, a propagation space, the quantitative, qualitative, mapping identity and the quantitative and qualitative measurements can be determined;
- for a considered urban area, only the qualitative and mapping identity and the qualitative measurements shall be determined.

Quantitative Identity of the Fire Risk

In order to determine the quantitative identity of the fire risk, Ri, considering a propagation space with well determined profile element, the following parameters showed be evaluated: the flame source in rest or in action, distant of d from the stake, it exists movements possibly leading to contact, that is to say, possibly variable d with a value between λ (bigger distance of the space concerned) and *0*, drag the flame bursting.

Qualitative Identity, Characteristics of the Urban Centre and Assessment of the Fire Risk

Consider the zones or urban area above, divided in several zones; D1, D2, Di… danger partners, with their characteristics. To characterize the urban area, consider first, zones by types of habitat, dominating factors and associate them to those zones of habitat: causes of fire risk, zones of propagation, stakes (size, in flammability), flames sources (degree of activity), movement leading to a similar point, d distance, identity and measure of dominating fire risk (one consider by simplification, dominating fire risk and a probability of its presence), the explanatory factors. These information have been developed above and require a summary.

Risks are determined while considering the knowledge of the function of every building, its possible content, because the envelope that is the roofing is not raised.

To describe the zone, requires to simplify and to admit the risk in the totality of every zone. One admits this uncertainty otherwise; it would be difficult to localize all risks of fire in the zone.

Mapping Identity of Risk in the Urban Centre

Considering data of the urban centre, tools of data processing, their use, the mapping identification is an automatic method that uses remote sensing. Considers the extent of the urban area, one digital a map and established another one by remote sensing for the updating, using also an aerial photograph of the zone [4].

The isolated zones (by function) include, administrative zone, commercial zone …….

We admit the same uncertainty and simplification as for the case of the qualitative identity.

The map of zones of the urban centre have been established and associated to every zone corresponding risk characteristics (causes, stakes, flames sources, movement, identity, measure, explanatory factors…). These leads to the mapping identity of the fire risk.

Quantitative Assessment of the Fire Risk

The measurement of risks has been done by quantitative assessment, while taking into account the factors of existence of fire risk and the point of bursting flame with its neighbourhood.

Qualitative Assessment of the Fire Risk

In order to globally assess of the risk in a extensive zone, the different factors that have enabled the mapping identity have to be appreciated. They include:

- the scope of factors of fire risks;
- the size and the inflammability of stakes;
- the activity of the flames sources ;
- the degree of easiness of propagation of the fire;
- the manifestations.

Impacts

It is the manifestation of fire risk and the occurrence

The manifestation of fire risk is linked through anxiety, insecurity, uncertainty at the level of evolution of the situation, occurrence of catastrophes

In order to show the manifestation of danger, the state of the elements (stake-flame source) of different dangers should be observed so as to know precursor factors of the presence of dangers. The inflammability, size of stakes, the degree of the action flame source, the scope of movements must be assessed.

Conditions of Occurrence

Occurrence conditions are studied on status profile of the elements of risks.

The conditions of occurrence depend on the state of elements. Let the zone of the urban area be definited, the movement between source flame and stake can intensify and there will be occurrence of catastrophe. Theses conditions are obtained by applying bursting flame to the whole elements of profiles.

3. RESULTS

Occurred fire Catastrophes

Several fires have occurred in the city of Yaounde particularly, in markets, quarter with spontaneous habitats, the industrial and dangerous product storage zone:

1- 18-02-1998; Nsam neighbourhood (Yaounde*): **burning of people, petrol and property in the storage[2] zone***, following a manipulation of petrol by these people. More than 140 dead, several injured, loss of fuel, lost of property;

2 - 08 -1992, 01-02-2003; Yaounde: ***Fire disaster in the Mokolo market*** with considerable material loss;

3 - 04-05-03; Yaounde: violent joinery fire at Avenue Germaine[2], considerable materials loss…

Causes of fire in markets are most often, unknown. In quarters with spontaneous habitats, it is mostly favoured by the use of candles, saw-dust, gas, and electric connections. In dangerous zones, they are owed to the manipulation of fuel.

ELEMENTS OF DEFINITION OF FIRE RISK

Fire Risk Causative Factors intention to light fire; human carelessness; manipulation of the dangerous product in storage and dwelling zones; carelessness of cigarette sticks; electric failure along the roads, lack of access in zones of spontaneous habitats, high density houses in a spontaneous habitat zones; use of several types of fire: wood fire, saw-dust, stove, gas in markets and dwelling zones; lack of water storage facilities; laxity of fire fighters brigade, manipulation of fuel in the petrol stations; temporary state of the quality of building materials, followed by the use of lamp, fire, candle as means of lighting in spontaneous habitat zones, transportation of dangerous product, presence of sparking utensils in welding workshops in the spontaneous habitat zone;

2 - Cameroon National fire fighting brigade

houses in industrial and fuel storage neighbourhood zones, presence of casual and pirated connections follow-up by the use of high electrical tension appliances in spontaneous habitat zones; electric shocks in the transformer; warming-up of the vehicle carburettors.

Flammable Materials: paper; wood, metallic sheet, straw, electric cable, gas, bamboo, grass, oil, fuel, kerosene, carcass of vehicles, clothes, plastic, polystyrene, dead leaves. These materials have a class of inflammability μ, that varies from *1* to *6*, μ ,being a natural whole number. These generic elements are of three types (strong, liquid, sparkling) and form four class of fire, class A or fire of solids, class B or fire of solids which can be liquidized, Class C or fire of gas, D class or fire of metals.

Flame Sources: sticks of match, fire, candles, cigarette sticks, explosives, sparks, temperature, thunderbolt, electric bow, bulb, short circuit, lamp, fire stove, fire gas, fire wood, fire sawdust, transforming and carburettor. Flames sources have a degree of χ activity j that ranges between *1* and *6,* χ being a natural whole number.

According to cigarette sticks, stick of match, temperature, the following zones can be distinguished: dwelling zones, zones of parking, industrial zones, administrative zones, commercial zones, social facilities zones.

Based on fire the following can be identified: zone of dwelling, industrial zone, commercial zone.

The following can be named based on candles: dwelling zones, commercial zones, social facilities zones.

Concerning sparks, the following zones can be identified: industrial zones, zones of habitat, commercial zones, social facilities zones, storage cistern, harbour equipment, storage silo, and transformation machines.

Stakes: stakes of particular nature are: building (building in wood, framework in woods and cover in metal sheet), dangerous products industrial facilities, equipments, vehicles, person, means, products of sale.

According to the building the following stakes exist:

- Function buildings: social facilities buildings, commercial buildings, industrial buildings, dwelling buildings,

- Administrative buildings: service buildings, printing press, state police, gendarmery, treasury,

- Social equipment buildings: schools, secondary schools, churches, hostels, day nursery schools, sporting complex.

- Commercial buildings: commercials shops, banks, pharmacies, petrol stations, printing press, parking space, private service.

- Dwelling buildings: houses, residences, motels, garage, shacks, wood houses.

According to vehicle stakes are: aeroplane, car, motorcycles, and trains.

According to dangerous products include: kerosene, gas, chemicals, paint, explosive,

According to equipments, the following can be distinguished: furniture, oil, papers and cardboards documents, clothes, oil, gas, sawdust, wood, plastics.

Classification of building according to the activity of the zones.

Stakes of the industrial zone: factory, warehouse, kerosene, gas, chemical, paint, explosive, storage cistern, petrol station, garage, storage silo, transformation machines.

Stakes of the parking space: stakes of the dwelling zone, commercial zone.

Distances Between Stake and Flame Source

Distance α (α has a value which varies between *0* and λ : $0 \leq \alpha \leq \lambda$) λ: longer distance between stake and flame source in a space of propagation or an isolated room.

Movements Between Stake and Flame Source

Movement to zero displacement, movement to displacement of the stake, movement to displacement of the flame source, movement to any other displacement, movement to indirect displacement.

Status Profiles of Elements

Let all the different cases of the system (stake, flame source, distance α) be studied. Its profiles form of state of elements of fire risk:

13 summarised cases define these profiles: stake - flame source - α gap: ($\alpha \geq 0$).

P_1- stake with prompt inflammability, plus existing flame source and in action: high energy, but $\alpha \neq 0$;

P_2-stake with prompt inflammability, plus existing flame source and in action, but $\alpha \neq 0$;

P_3-stake with expeditious inflammability, plus existing flame source and to rest, but $\alpha \neq 0$;

P_8-stake with expeditious inflammability, plus existing flame source in action, small energy, with $\alpha \neq 0$;

$\mathbf{P_i}$……

Urban Zone Types and Extent

The Yaounde urban area is divided into many zones in which are associated several characteristics.

The considered **s**ized include: the fire span paint and its neighbourhood, extend zone, whole urban environment.

The different determined zones require a classification: classification according to the geographical limits, classification according to the physical appearance, classification according to the stake, classification according to the generic element of the flame, classification according to the propagation of fire.

Classification according to the geographical limits

Zones are distinguished according to divisional, district, communal, relief and occupational boundaries.

- Department 1, department 2, department 3, department 4……
- district 1, district 2, district 3, district 4,……
- communal 1, communal 2, communal 3, communal 4;
- plateau1, valley 1, medium slope 1……
- quarter with spontaneous habitat, quarter with structured habitat… quarter with spontaneous habitat k, structured quarter.

The Summary of Zones is:

Zone 1 : spontaneous habitat zone 1; Zone 2 : spontaneous habitat zone 2 or intermediate habitat zone ; Zone 3 : structured habitat zone 1 or average standing résidential zone; Zone 4 : structured habitat zone 2 or high standing résidential zone; Zone 5 : social facilities zone; Zone 6 : administrative zone; Zone 7 : commercial zone; Zone 8 : industrial zone;

Zone 9 : dangereous materials storage zone; Zone 10 : packing space.

Possibilities of Flame Bursting

The risk of fire rests on possibilities of fire bursting gotten from the interconnected generic element that burns - element flames:

eclo1: metallic sheet - fire; eclo2: metallic sheet - explosive; eclo3: metallic carcass - fire; eclo4: metallic carcass - explosive; eclo5: vaporizing - fire

eclo6: petrol - stick of match; eclo7: petrol - candle; eclo8: petrol - cigarette sticks; eclo9: petrol - temperature; eclo10: petrol - explosion; eclo11: petrol - carburettor; eclo12: straw - fire eclo13: straw - stick of match; eclo14: straw -candle; eclo15: straw - cigarette sticks.

Propagation

Catalysts of fire are the elements that favour the propagation such as high coefficient of soil occupation, wind, high temperature.

As analysis shows the existence of:

- isolated points;
- sub-zones to high density with a appearance of continuity;
- the freestanding buildings with high scope;
- the occasional residential or other unequally distributed building;
- the public gardens or the reduced bushes;
- the free open spaces or esplanades;
- roads;
- rivers

All these zones apart the sub-zones, show a certain disparity in stake distribution.

The homogeneity of zones is not verified here, as forest areas and interfaces. This makes, very difficult the characterization of zones in relation to fire risks. For this reason, the fire risk in these zones shall be simplified.

Zones according to the propagation at Yaounde: spontaneous habitat zone, commercial zone, dangerous materials zone.

CHARACTERISTICS OF RISK AND ZONES

Types of Fire Danger

A follow up of the progressive setting up of elements of fire risk with a variation of $!$ between *0* and λ, enables to note that the danger of fire varies from the potential of the fire risk (*0* $!$ $!$., non-existent stake) to the fire (α *=0*), while passing by the risk and the potential of fire (from flame source to rest, $!$ *=0*).

Types of Fire Risk in the City of Yaounde

In relation to the nature: R_1: risk of fire of inhabited buildings, R_2,: commercial store fire risk, R_3: fire risk related to dangerous materials…….

In relation to the extent of places; R_4: risk of market fire……..

Identity of the Fire Risk in Urban Area

Quantitative Identity

Considering identification will start in a market sales shops in this area, which is built with wood, with $!$ by $!$ as dimensions of the shops, containing products which can be burst; then the movement between stake and flame source occurs such that α varies between *0* and $!$.

One notes that $!$ $!$. Therefore, there is risk of fire

In an store, one admits a ε_i **probability** for the consideration of a higher activity source flame.

Movements being uncertain, the precise places and the time of contact between stakes and sources flame cannot be known, thus we suppose a η_i **probability** of bringing together or contact to the place of stakes.

One consider a ξ_i **probability** for the fire risk to spread throughout the store.

Remarks: shops are small and nearly full, one considers stakes dominating on the total surface of the store.

For a given store, the existing risks are as follow:

R_i depends on characteristics of the profile P_i. The gotten risks are:

$$R_i = F\left[P_i\left(cla\ fla\ sou, !, cla\ enj\right)\right]:$$

$$R_{ipièce} = \left(P_{i\,ri\,éclo}\left(cla\ sou\ fla, \alpha, cla\ enj\right)\eta_i.\varepsilon_i.\xi_i; g\left(cla\ enj, \Psi, ...\right)\right)$$

$$R_{ipièce} = \left(\beta_i.\eta_i.\varepsilon_i.\xi_i; g\left(cla\ enj, !, ... \right)\right)$$

$$P_{i\,ri\,éclo}\left(cla\ fla\ sou, \alpha, cla\ enj\right) = \beta_i \text{ with}$$

$$PI_{i'} = F\left[P_{i'}\left(cla\ sou\ fla, 0, cla\ enj\right)\right] (\alpha: = 0)$$

$$PI_{i'\,pièce} = \left(P_{i'\,poéclo\ (cla\ sou\ fla,0,cla\ enj)}\varepsilon_i;\ (\eta_{i:}=1;\ \xi_i=1)\right.$$

$$PI_{i'\,pièce} = \left(\ _{i'}.!_{\ i};\ g\left(cla\ enj, !, ... \right)\right) \text{with}$$

$$P_{i\,ri\,éclo\ (cla\ sou\ fla,0,cla\ enj)} = !_{\ i'}$$

F : vector function; $P_{i\,ri\,éclo}$: probability of flame bursting in a store; g : function describing the scope of destruction of the stake; $!$: distance between flame source and stake; $cla\ fla\ sou$: degree of activity of the flame source; $cla\ enj$: level of inflammability of the stake ; Ψ : size of stake

For the potential risk PI: α : = 0 because potential situation means, stake and flame source are in contact, $\eta_{i:}$=1 because there is already contact between stake and flame source, ξ_i=1 because we have considered the fire risk to spread throughout the store

Determination of the probability of flame bursting

$P_{ri\ éclo}$ (sou fla, enj) = $P_{ri\ éclo}$ (cla sou fla, d, cla enj)

V enj = V_1m_1+ V_2m_2 + V_3m_3+ V_4m_4+ V_5m_5+ ……+ V_im_i

V_i is the volume of flammable material m_i , in the body of the stake

cla enj = cla (V_1m_1+ V_2m_2 + V_3m_3+ V_4m_4+ V_5m_5+ ……+ V_im_i)

We will considerer the most flammable level among the materials of the stake, as the flammable level of the stake:

cla (V_1m_1+ V_2m_2 + V_3m_3+ V_4m_4+ V_5m_5+ ……+ V_im_i) = cla (m_j)

cla (m_j) is the most flammable level of materials present in the stake [5].

$P_{ri\ éclo}$ (cla sou fla, d, cla enj) = $P_{ri\ éclo}$ (cla sou fla, d, cla (V_1m_1+ V_2m_2 + ….+ V_im_i)) = $P_{ri\ éclo}$ (cla sou fla, d, cla (m_j))

$P_{ri\ éclo}$ (cla sou fla, d, cla (m_j)) ≅ $\alpha X\ \beta Y\ \gamma / d$ + ……)

X Flammable level of the stake, has a value between 0 and 1;

Y Degree of activity of the flame source, has a value between 0 and 1;

d is the gap between stake and flame source, has a value between 0 and d_{max}

α, β et γ proportionalities coefficients, different from 0

The probability function $P_{ri\ éclo}$ has a value between 0 and 1; $0 \leq P_{ri\ éclo} \leq 1$

Table 1. Determination of the Existence Profile Concerned

(stakes-flame source)	-Activity -level -flame source inflammability	Level of stake inflammability	size of stake	gap *a* between stake and flame source	Corresponding profile
$stake_l$- fla_f sou	*cla fla sou*	*cla enj*	Size : Ψ	*a* stake- fla sou	P_x

$P_{ri\ éclo}$ (cla sou fla, d, cla (m_j)) ≅ $\alpha X\ \beta Y\ \gamma$ / d + ……) = ϕ (X.Y) / d + …….

$\phi = \alpha\ \beta\gamma$ and $\phi \leq 1$ (0)

After discussion about the existence of the probability fonction we obtain:

$P_{ri\ éclo}$ (sou fla, enj) = $P_{ri\ éclo}$ (cla sou fla, d, cla (m_j)) = (X.Y) / (d + 1) + …….

Determination of probabilities η, ε, ξ

There is three possibilities that the stake be near the flame source: movement of the stake to the flame source, movement the flame source to the stake, flame source and stake in movement. η = 1/3.

In taking account all flames sources $(sou\ fla)_i$, the probability so that highest activities flames sources be the dominating in the store is : $\varepsilon = \sum n_i / \sum nt_i$

The probability ξ so that the fire risk spreads in all the store, is: $\xi = S_{enj} / S_{pièce}$

$\sum n_i$: number of higher activity flames sources

$\sum nt_i$: total number of flames sources

S_{enj} : surface covered by the stake

$S_{pièce}$: total surface of the store

For a store the existent fire risk is:

$R_{pièce}$= ($P_{ri\ éclo}$ (cla sou fla, d_1, cla enj) .η.ε.ξ ; g(cla enj,taille enj, …….))

$R_{pièce}$ = ([X.Y / (d + 1)] .η.ε.ξ ; (X, V_{total}))

$R_{pièce}$ = ([X.Y / (d + 1)] .1/3.($\sum n_i / \sum nt_i$). (S_{enj} / $S_{pièce}$) ; (X, V_{total}))

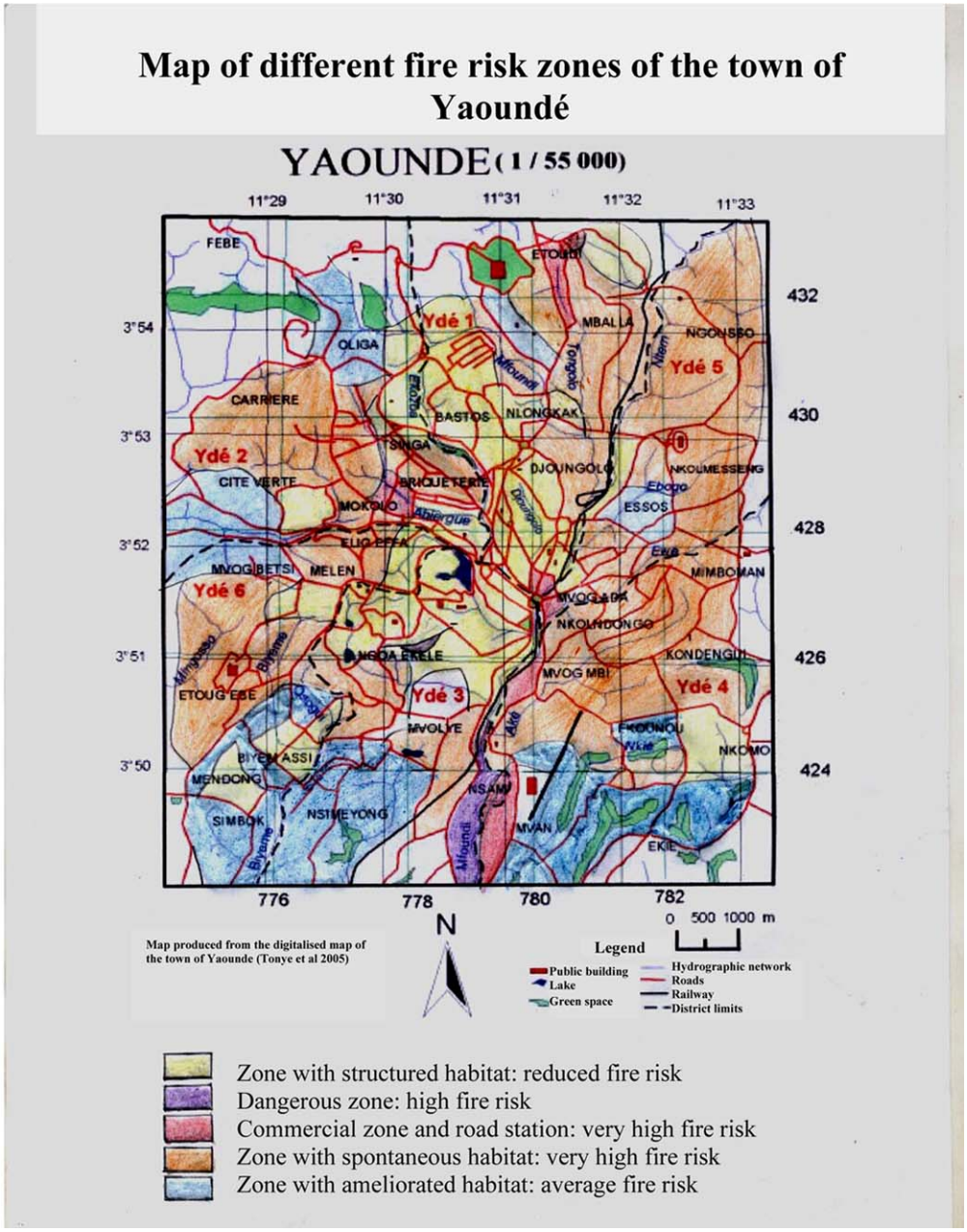
The fire risk and potential in every store of a propagation zone shall thus be determined.

Qualitative Identity and Characteristic of the Urban Area

The Yaounde urban centre is divided into several zones in which are associated several characteristic [6], (Table below).

Table 2. Types of Zones and Fire Risks Characteristics in Yaounde Town

	Zone a= spontaneous habitat zone(1 and 2)	Zone b= structured habitat zone (1 et 2)	Zone c= road station and administrative zone	Zone d= administrative and social equipment zone	Zone e =dangerous and industrial zones
Past fires	Destructive and frequent [7]		Destructive and frequent		Destructive and frequent
Causes	more numerous causes, interdependent and bound to the life of poverty ; extended propagation zone	Less numerous Causes, and independent Propagation zone	Numerous Causes ,and extended propagation zone	Less numerous Causes, independent and reduced Propagation zone	Reduced Causes, independent and reduced propagation zone
Stakes (size and in flammability)	Constructions in very tight boards, frameworks wood and cover in metallic sheet, flammable interior equipments, more raised in flammability	more resistant buildings, average inflammability of flammables interior equipement,	buildings in very tight boards, frameworks wood and cover in metallic sheet, , sale products (clothes, plastic matters,…), high in flammability flammable interior equipments,	buildings in resistant wood, frameworks wood and cover in metallic sheet, medium flammability of flammable interior equipments	Size or storage products high, very high inflammability [8]
Flames Sources (degree and activity)	the most numerous flames Sources	reduced flames sources	numerous flames Sources	reduced flames sources	reduced flames sources
Dangers (identity, site, measure)	Risks and potential of fire very high and spread in building	small and reduced fire Risks in buildings	Risks and potential of fire very high and spread in buildings	small and reduced fire Risks in buildings	Risks and potential of fire very high and spread in buildings
Bursting flame, probability of occurrences catastrophes	very high Mobility of populations, confused activities and space uses; high probability of catastrophe occurrence	medium Mobility of populations, activities and distinguished uses of space, low probability of catastrophe occurrence	very high Mobility of populations, activities and confused space uses; high probability of catastrophe occurrence	medium Mobility of populations, activities and distinguished uses of space, low probability of catastrophe occurrence	medium Mobility of populations, activities and no- appropriated uses of space, high probability of catastrophe occurrence
Manifestations	high Anxiety, accentuated insecurity, uncertain evolution, sudden change	no manifestation	high Anxiety, accentuated insecurity, uncertain evolution, sudden change	no manifestation	high Anxiety, accentuated insecurity, uncertain evolution, sudden change



Flow chart: Constitution and evolution of components fire risk phenomenon.

Mapping Identification in Urban Area

The mapping identification is here the semi-automatic mapping using remote sensing.

Below is a map showing the different risk zones in the Yaounde urban area.

Assessment of the Fire Risk

Measurement of fire risk. It is the matrix:

M (occurrence, intensity, vulnerability)

$$M = (\ _i\#_i.\ _i.!_i\ ;\ !\ ;\ g(cla\ 4, \tfrac{3}{4}Vtotal, ...)) = (\ _i\#_i.\ _i.!_i\ ;\ \ ;! .....))$$

(cla enj =cla 4; V(mi)=3/4Vtotal because of our consideration)

Measurement of the Potential of Fire

$$M' (P_{i'poéclo}\ (cla\ sou\ fla, 0, cla\ enj)\ !_i\ ; g(cla\ enj, !\ .....)) = (\ _{i'}.!_i\ ;\ \ ;! .....)$$

$P_{i\,ri\,éclo}$: probability of flame bursting in a store; g : function describing the scope of destruction of the stake; $!$: distance between flame source and stake; $cla\ fla\ sou$: degree of activity of the flame source; $cla\ enj$: level of inflammability of the stake ; $!$: size of stake; $!$: high number, $!$: high number; $!$: bigger destructions, $!$: bigger destructions.

Note that there's a difference between quantitative identity and quantitative measurement of the fire risk ; here quantitative identity does not take in account the intensity of the risk.

Table 3. Insecurity Bound to Fire Risks or Manifestation of Fire Risk State

Stake with Prompt Inflammability + Existing Flame Source and in Action: But $a \neq 0$								
Few Important Movement			**Movement with Higher Span**			**Movement Very Higher Span**		
Possibility of destruction	Climate of insecurity	incertitude	Possibility of destruction	Climate of insecurity	Incertitude	Possibility of destruction	Climate of insecurity	Incertitude
reduced	accentuated	higher	average	accentuated	higher	higher	very accentuated	higher

Assessment (Qualitative)

Here, the assessment of fire risks relative to an extended zone is recalled. It is: the scope of factors of fire risks, the size and the inflammability of stakes, the activity of sources flames, the degree of easiness of propagation of the fire, the manifestation.

This assessment is done above in the Table **2**.

Impacts of Fire Risk

Table i: Insecurity bound to fire risks……

P_i: stake with slow inflammability, plus existing flame source, in action and with high energy

b). Conditions of Occurrence

Consider zone of the urban area be definited, the movement between source flame and stake intensifies: there is occurrence if and only if:

-the flame source is in activity;

-the class of inflammability of the stake is either high or low;

-the existing movement decreases by a value d until the value zero.

The study of these factors of occurrence through the different fire risks elements existence profiles enable to confirm the occurrence, by simulation flame bursting script of the different cases of profiles [9].

The case of the Nsam disaster fire in Yaounde, verifies the condition of the profile P_5 above:

Stake with prompt inflammability, plus source in rest, but in contact or $a = 0$:

Condition of occurrence of the catastrophe: "flame source burned "leads to flame bursting.

4 - CONCLUSION AND DISCUSSION

In determinist universe, it has just been shown that the evolution of the phenomenon of fire risk is a stake in the implementation of the characteristic elements of the fire risk in urban area. The urban fire risk vulnerable zones can be differentiated based in the elements and characteristics of fire risks. Each zone presents a detail of information on fire risk. The gravity of the risk increases with the decrease in the standard of living in the zone. Factors of fire risk appearance can be distinguished based on: the utilization of electrical devices, human behaviour and, the nature of the stake.

Table 4. Insecurity Bound to Fire Risks

Stake with Prompt Inflammability + Existing Flame Source in Rest: $a = 0$: (*Situation of Fire Potentiel)*								
Few Important Movement			**Movement with Higher Span**			**Movement Very Higher Span**		
Possibility of destruction	Climate of insecurity	incertitude	Possibility of destruction	Climate of insecurity	Incertitude	Possibility of destruction	Climate of insecurity	Incertitude
Very reduced	Slightly accentuated	slightly higher	Very reduced	slightly accentuated	slightly higher	Very reduced	slightly accentuated	Fslightly higher

Table 5. Insecurity Bound to Fire Risks

Stake with Prompt Inflammability + Existing Flame Source and in Rest, But $a \neq 0$:								
Few Important Movement			**Movement with High Scope**			**Movement with Very High Scope**		
Possibility of destruction	Climate of insecurity	incertitude	Possibility of destruction	Climate of insecurity	Incertitude	Possibility of destruction	Climate of insecurity	incertitude
Very reduced	Slightly accentuated	Slightly high	Very reduced	Slightly accentuated	Slightly high	reduced	accentuated	higher

The disparity and the lack of homogeneity in the nature of the property exposed to fires, makes difficult the determination of their inflammability degree, as well as, the types of fire risks.

The incontrollable variation values of factors of fire aggravation leads the determination of the limits of propagation zones in an absolute manner extremely difficult.

The quantitative identification, although very strenuous, is quite necessary.

On the whole, Yaounde is exposed to risks of fire

On a theoretical point of view, it is rolled that the characteristic elements (factors of apparition of the risk, stakes) of fire risk are indicators of urban planning. The principles of existence of fire risk have been established all along this survey, can be applied in other urban area than Yaounde.

The analysis of fire risk and its impact provides information for the preparation of a fire-fighting strategy and risks in urban area.

Table 6. Insecurity Bound to Fire Risks

Stake with Expeditious Inflammability + Existing Flame Source, in Action and with High Energy, *a= 0*								
Few Important Movement			**Movement with Higher Scope**			**Movement Very Higher Scope**		
Possibility of destruction	Climate of insecurity	incerti-tude	Possibility of destruction	Climate of insecurity	Incertitude	Possibility of destruction	Climate of insecurity	incertitude
Very reduced	Slightly pronounced	Slightly high	reduced	accentuated	high	average	accentuated	higher

Table 7. Condition of Occurrence of Catastrophe

Type of Profile	**Characteristics, Stakes, Flames Sources, Gap *a* Between Stake and Source Flame for Occurrence of Bursting Flame**
P_1	Stake with prompt inflammability, plus existing flame source and acting, but the distance $a \neq 0$. Condition of occurrence of catastrophe: the distance between the stake and the flame source $a = 0$, leads to the flame bursting.
P_2	Stake with prompt inflammability, plus existing flame source and action, high energy, but of distance $a \neq 0$. Condition of occurrence of catastrophe: the distance between the stake and the flame source $a = 0$, favours flame bursting.
P_3	Stake with prompt in flammability, plus existing flame source and in rest, but the distance $a \neq 0$. Condition of occurrence of catastrophe: the distance between the stake and the flame source $a = 0$, the flame source burned leads to the flame bursting.
P_4	Stake with prompt in flammability, plus existing flame source and in action: high energy, in contact $a = 0$. Condition of occurrence of catastrophe: (already true), fire acquired
P_5	Stake with prompt in flammability, plus existing flame source and in rest, but the distance $a = 0$. Condition of occurrence of catastrophe: (flame source burned leads to flame bursting
P_6	Stake with prompt in flammability, plus non-existent flame source. Condition of occurrence of catastrophe: (no condition): no fire
P_7	Stake with prompt flammability, plus existing flame source in action, in contact or $a = 0$. Condition of occurrence of catastrophe: (already true), fire acquired
P_8	Stake with slow in flammability, plus existing flame source, in action, low energy, $a \neq 0$ Condition of occurrence of catastrophe: distance between the stake and the flame source $a = 0$, leads to flame bursting.
P_9	Stake with slow in flammability, plus existing flame source, in action, $a = 0$, element of fire transfer. Condition of occurrence of catastrophe: (already true), fire acquired.
P_{10}	Stake with slow in flammability, plus existing flame source, in action, $a = 0$. Condition of occurrence of catastrophe: the presence element of transfer leads to fire.
P_{11}	Stake with slow in flammability, plus existing flame source, in rest, $a \neq 0$: 2nd threshold. Condition of occurrence of catastrophe: (distance between the stake and the flame source $a = 0$, the flame source burned, presence of the element of transfer) leads to the flame bursting.
P_{12}	Stake with slow in flammability, plus source non-existent flame source. Condition of occurrence of catastrophe: no fire.
P_{13}	Stake with slow in flammability, plus existing flame source in rest, $a = 0$: 1rst threshold. Condition of occurrence of catastrophe: (the flame source burned, presence of the element of transfer) leads to flame bursting.

Solutions

The current solutions (measures taken, respect of security rules, proper study of preventive measures) have some limitations because they don't take the existing realities into consideration.

The environment of the fire risk zone being known, one must describe the situation, that is:

- the urban area in survey;
- the past fire history (causes,….);
- the determined factors of fire risk concerned and their dependence relationships;
- the determined all characteristic of existing fire risks (identity, measure, localization, impacts) and their dependence relationships;
- to determine victims and the other intervening parties;
- to determine their contribution to the reduction of fire risks and reports of dependence;

Solutions to risks of fire are of two-fold: solutions of prevention and solutions of precaution.

Description of the situation

Presentation of the Surveyed Urban Area in Survey

The survey has been done in a habitat zone within the urban area. The latter presents the features of big cities in the third-world: demographic explosion, spontaneous occupation of space, growth rhythm beyond the power of state, more than 70% of the populations carry out some commercial and casual activities. Targeted zones are not a matter for any plot. The urban data describe the occupation of space, the nature of building, the density, the accessibility, the management of activities, electric networks, and water networks.

Past Fire History

Retrace the history of fire occurrence including the reasons, their scope, their measurement, the frequency of occurrence, losses, the intervention of fire fighters, the mobilization of affected people (intervention, manifested sensitizations, measures of security, manifestation)

Factors, Risks of Fire and Zones, Features and Impacts

The urban area is divided into several zones, which are associated to several features, factors and fire risks (see above).

Determination of Considered Solutions

Solutions to fire risks are divided into two main categories: solutions of prevention and solutions of precaution. The type of solution to consider depends on the nature of the factor of the existing risk:

- the suppression of causative factors of fire risks requires a preventive solution. On the contrary, the following fact " the risk 0 doesn't exist;" is confirmed.
- Precautionary measures are necessary.

The two reasons of fire risks have been determined (discussed above) while referring to the two types of solutions (prevention and precaution).

Reasons Requiring a Solution of Precaution

The concerned reasons are as follow:

Intentional fires or criminal reason, human carelessness, manifestation of the thunderbolt, dry garbage deposits in the field, manipulation of the dangerous product, negligence of cigarette sticks, , influences of wind, activities in company, use of several types of fire: wood fire, sawdust, stove, gas, use of the lamp, of fire, of the candle as means of lighting, transportation of an explosive product, high temperature , presence of match stick, presence of sparking element, presence of gas, electric discharge in the transformer, short circuit.

Reasons Requiring a Preventive Solution

The concerned reasons are the following:

Other uses of fire, effects of mass tension, electric failure, agreement of importance to the fires of artifice, conservation of precariousness of manufacture equipment and rules of prevention, scratch handicraft maintenance, lack of access in zones, high density of houses in zones, lack of water points, laxity of fire fighters, manipulation of fuel in petrol stations, temporary state of the quality of building materials, housing in an unsuitable zone, presence of the dry bushes, difficulty of flight, presence of casual electric connections, presence of pirate connections, utilisation of high tension, warming-up of the carburettors, use of fire, of candle as means of lighting.

Intervening Parties, Solutions

For an adapted and efficient solution, intervening parties such as populations and authorities concerned must complementarily respect their role. The mobilization must be efficient and a team of work include the representatives of every intervening party must be set up. This team must examine all changes and intervention to carry out in each zone. All concerned parties must confront their proposals to solutions; measure the impact in order to circumscribe an efficient and satisfactory solution.

On the whole, the team must:

- acquire the necessary knowledge of description of fire risks and features of the urban area;
- isolate the different zones according to risks of fire;
- examine all changes and interventions to do in every zone;
- confront propositions of solutions, to measure the impact in order to delimit a satisfactory and efficient solution;
- To define the role of every representative and its mobilization;

Concerned people count themselves among service beneficiaries, traders, service owners, individuals (owners of buildings and administrative and industrial services, owners of vehicle), tenants, the petrol stations, craftsmen, carpenters, the governmental processes.

The government authorities are concerned with all decisions for the application of solutions, it is: the Direction of the Civil Protection, fire fighting brigade, the AES - Sonel, the Ministry of Transports, Insurances, fuel producers, the local Collectivities, the Ministry of the town planning and the Urban Development.

Solutions are four in number:

- it is necessary to warn, that is to eliminate some factors of fire risks;
- it is necessary to set up a permanent intervention strategy in case of fire;
- it is necessary to take measures of precautions; it is necessary to a particular behaviour of sensitivity and mobilization for the irreducible fire risks;
- it is necessary to plan working spaces, that is to organize spaces [10], to create activities in order to raise standards of living of populations and some factors are going to disappear.

For a Solution of Intervention

* The fire fighting brigade must have a permanent intervention device in case of fire. The fire fighting brigade must have risk maps associated to geographic information system in order, to develop the efficiency of intervention [11]. The device of intervention is prepared according to factors aggravating fire (inflammability of the stake, its size, wind speed, temperature, effect of the thunderbolt, criminal fire frequency).

*The fire fighting brigade must be sure that: public buildings or large un-isolated building to the flames are well equipped with fire extinguishers;to install in the possible measure, a device of alarm for all stakes in case of bursting flame.

* Occupants of houses and services must know the protective rules in case of fire, including the possibility of calling the fire fighting brigade [12].

* The Direction of the Civil Protection, the local collectivities and the administrator in place must proceed to an intense sensitization on the recurrent past fire reasons, interventions, and security measures to take. They should also endeavour to respect the above rules and regulations:

For a solution of precaution, decision-makers must lead the sensitization (medias, teaching, information) of the concerned populations, to create an information unit in every risk zone, to display maps of fire risks and all elements of risks above.

It is necessary to a continuous mobilization; users must lead a high monitor, that rules of security are respected.

For a solution of prevention, it is necessary to suppress some factors of fire risks, to ensure an adequate change (taking account of limits or possibilities concerning them, and the authorities concerned) solving thus, the problem of spontaneity in the work of spaces [13].

It is necessary to proceed to the physical modification: to change the nature of stakes, to change building materials, to use some resistant materials to fire, excluding to maximum past fire promoting reasons.

It is necessary: to create ways of communication, to control fire activities and the work of spaces, to suppress pirate and casual electric facilities, avoid the use of candles for lighting, to build using resistant material, in order to prevent the propagation of fire [14].

For a solution of change of the urban area, the ministry of the urban development and the habitat, the local Collectivities, non-governmental organisations must control the work of spaces and create activities in order to raise standards of living of populations by so doing, some factors are going to disappear. The Direction of the Civil Protection must make sure of the respect of these requirements.

The considered solutions vary with the zone. Solutions exist on three main plans: immediate solutions, long-term solutions, necessary solutions.

The type of solution is chosen according to the existing realities. The necessary solution is considered to avoid the worse: the device of intervention must always be ready for its application in the extinction of the fire of zone.

The envisaged solution precedes the long-term solution to a certain extent; it is said in this case to be necessary. It is often justified by the lack of means, the length of the time to execute the long-term solution which is nothing else but a preventive solution.

In another way, the immediate solution is the solution of precaution, the risk being unavoidable; this solution is equally justified by its easy execution, because it depends on people's behaviour.

Changes and Interventions in the Different Zones in the City of Yaounde

1) Zones of spontaneous habitat (Mokolo, Madagascar, Carrière, Bankolo, Briqueterie, Nkomkana, Emana, commercial zone; parking road zone …..):

These quarters must pass through four solutions such preventions, precautions, changes and intervening parties. The solutions of prevention and changes are most important.

For the prevention and the change, the following factors must be eliminated:

Other uses of fire, effects of mass tension, electric failure, agreement of importance to the fires of artifice, conservation of precariousness of manufacture equipment and rules of prevention, improvised handicraft maintenance, lack of access in zones, high density of houses in zones, lack of water point, laxity of fire fighters, manipulation of fuel in the petrol stations, temporary state of the quality of building materials, housing unsuitable areas, presences of dry bushes, difficulty of flight, presence of casual and pirated connections, , use of high tension devices, warming-up of the carburettor of the vehicle, use of fire and candle as means of lighting.

It is necessary to proceed to physical modification so as to change the nature of stakes, building materials, use more resistant materials to fire, excluding to the maximum the past causes of fire disasters.

It is also necessary: to create ways of communication, to control activities of fire and the organisation of space, to stop the pirate and casual electric facilities.

The ministry of the urban development and the habitat, the local collectivities and non-governmental organisations must control the planning of space and create activities in order to raise standards of living of populations and this will lead to the disappearance of some factors. The Civil Protection Direction must verify the respect of these requirements.

For a solution of precaution, decision-makers must lead the sensitization (medias, teaching, information) of the concerned populations, to create an information unit in every district in charge, of displaying maps of fire risk zones and all elements of risks above.

It is necessary to a continuous mobilisation that users must lead a high monitor, to observe rules of security in relation to:

Intentional fires or criminal reason, human carelessness; thunderbolt manifestation, dry garbage deposits in the field, manipulation of the dangerous product, negligence of cigarette sticks, wind influences, activities in enterprises, use of several types of fire (firewood, sawdust, burner, gas, use of the lamps, candles as means of lighting, transports of explosive products, high temperatures, presence of match sticks, presence of sparking elements, presence of gas, electric discharge in the transformer, short circuit.

The device of intervention must be ready in these fire risk zones by the elements of the fire fighting brigade.

2) Structured habitat zone; average standard residential zone; high standard residential zone; social facilities zone; administrative zone: commercial zone(Bastos, Santa Barbara, camp sic Green City, Messa, Longkak, Medong, central market, Quartier du Lac, central town……

These zones of structured habitat don't present problems of prevention and change, but are rather more pre-occupied by problems of precautions.

The solutions of precaution announced above will be applicated.

3) Dangerous zone: industrial zone, zone of storage of dangerous materials. Road network to transport dangerous explosives (Nvan, Emana, Nsam, Mvog Mbi….).

These zones are essentially suitable to measures of precautions and interventions which have been discussed above.

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