Management of acoustic risks for buildings near airports

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A B S T R A C T

Global population growth leads to a rapid urbanization of big cities and the development of transport infrastructure (airports, railway and bus stations). The strong urbanization in the cities of developing countries leads to a gradual rapprochement of dwellings and companies of airport zones. A fact that is real in Mali, where Bamako airport area has become an inhabited urban zone for some years by a part of the population. Given the importance of Bamako's airport traffic (West African crossroads), the proximity of the dwelling houses must receive the authorities and scientist's attention on the occupants' safety and quality life. The noise levels generated all around the airport zone throughout landings and take-offs by different aircraft types require an assessment of the acoustic noise level, the level of noise exposure and the building acoustic performance near the airport for users comfort and quality of life.

In this article, we give in one hand the general notions on the inhabitants discomfort indicators, the building acoustics and, on the other hand, non-quality identification, and the discomfort factors whose resolution contributes to improving the building acoustic and environmental performance. These assessment studies are based on acoustic measurements and in-situ surveys from construction actors and users. Data from these surveys are processed with an evaluation methodology developed to improve knowledge and strategies aimed at preventing or minimizing the acoustic risks near airports. The capitalization of knowledge resulting from this study can serve as experience feedback through good practices advocacy and corrective and preventive solutions for building construction and renovation projects.

1. Introduction

Every day, in urban and rural areas, noise generated by the use of the transport of infrastructures (road, rail, airport and industrial) can increase the life quality and the populations' environment in adjacent areas of these infrastructures. This twenty-first-century economic development is marked by the spectacular demand for air transport, including people and good transportation.

Today, this growing demand for air traffic is one of the main challenges faced by the aviation industry due to congestion in many airports, mainly hubs (Flores-Fillol, 2010).

Reducing the environmental impact due to high traffic demand creates serious problems in balancing airport expansion requirements (Arntzen and Simons, 2014). The nuisance social impact due to the use of these airport platforms can be charged, because of their impact on the health and life quality of the airport buildings inhabitants. Nowadays, aircraft noise is a particular problem during landing and take-off (Ignaccolo, 2000). A noise described as unwanted is known to have several undesirable effects on humans, such as hearing loss, communication interference. The study results conducted in France reveal that aircraft noise is one of the main causes of deterioration in life quality and an environmental dissatisfaction source (Faburel et al., 2006).

The aircraft noise influence on sleep, stress levels, anxiety, depression, psychological morbidity, boredom, hypertension and coronary heart diseases have been demonstrated in studies by some authors (Vogiatzis, 2012; Ozkurt et al., 2014 and Janssen et al., 2014). Studies on the sleep disturbances estimation reveal a relationship between the awaken people percentage and the noise levels (Wijnen and Visser, 2003).

WHO and other studies indicate that approximately 120 million people suffer from impaired hearing worldwide (Vogiatzis, 2012). Among the extra-auditory health effects of environmental noise studied, four were taken into account by the working group for the construction of the risk assessment method. These are those for which dose-response curves are available in some exposure situations and have been

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reported in the WHO Burden of Diseases documents (WHO, 2011). These include immediate effects (disturbed sleep and discomfort), medium- and long-term effects (learning disabilities and myocardial infarction).

The urban sound environment management has been the subject of much research works despite the complexity of the subject, linked to the subjective and contextual nature of the noise nuisance feeling. Most studies point to a continuing trend of economic growth in emerging countries, with global air traffic increase. The world market Airbus forecast 2015–2034 currently shows that 47 aviation megacities are concentrated on > 90% of long-haul flights and nearly one million passengers per day, and that 39 of 47 know various levels of congestion (Airbus, 2014; Rodríguez-Díaz et al., 2017).

In addition to the airport's expansion and airport platforms, there is a high demand for housing due to demography increased in developing countries. This high demand for urbanization in many large cities is recorded by the rapid rapprochement between dwellings and airports (Ganic et al., 2015).

There is an increase in the number of people affected by noise from air traffic. In recent years, numerous studies have been carried out on air operations negative effects on local residents' inhabitants. They emphasized the aircraft noise effects on property values and the laying out territory around the airport (McMillen, 2004; Morrell and Lu, 2000). The reduction and noise control become major challenges, both quantitatively and qualitatively, in airport buildings. As a result, it is necessary today to guarantee the life quality, the peace and a minimal comfort zone for inhabitants living near airports.

The life quality of these buildings users and the protection of the environment from noise nuisances can be achieved through appropriate measures such as compliance with noise protection zones (as in some developed countries), the use of adequate building techniques for buildings in airport areas such as buildings acoustic insulation or land use procedures (Ganic et al., 2015). Therefore, it is necessary to carry out evaluations of:

- The noise nuisances impact on the inhabitants of the airports surrounding areas;
- Airport buildings acoustic performance, etc.

This document proposes a process for assessing the buildings in the airport zones acoustic performance. The study objective is to provide building actors with a sound insulation procedure for dwellings in airport areas in order to facilitate their implementation and to optimize their results from a technical point of view. The state of the art concerns the concepts of annoyance indicators or the inhabitant discomfort, the building acoustics and the methodology (Camara et al., 2016; Camara et al., 2017; Kamsu-Foguem, 2016; Kamsu-Foguem and Tiako, 2017) is based on the risk factors affecting acoustic performance evaluation of the airport zones buildings. A survey of acoustic measurements (perceived noise intensity) in a building of Bamako airport area, field surveys of residents and interviews with building construction actors are envisaged.

The collected data during these different stages allow us to:

- On the one hand, to estimate the comfort level within the experimental building compared to the recommended norms, to identify the need (users and project managers), to identify the difficulties of project managers in order to master them;
- On the other hand, to propose good practices for renovations of existing buildings, to integrate the useful experiences of one another's concerns for a better decision-making for future construction projects.

To ease understanding, the paper is divided into five sections. Section 2 provides some contextual elements of the state-of-the-art about noise pollution in areas surrounding airports. Section 3 presents the adopted methodology including information elicitation, acoustic measurements, data analysis and risk assessment. In Section 4, an illustrative case study concerning acoustic performance evaluation in a building area of the Bamako airport. The discussion with lessons learned is examined in Section 5. The conclusion and perspectives are offered in Section 6.

2. State of the art: aircraft noise exposure and building acoustic performance

2.1. The noise evolution over time

Airplane noise is an unwanted sound that can cause psychological and physical stress to people who are exposed to it (Singh and Dev, 2010). The noise threshold is the maximum level of noise allowed in the environment in order not to cause human health and environmental comfort perturbations (Sondakh et al., 2014).

Aircraft noises have a certain random nature, these noises sound level, as measured by a sound level meter, corresponds to an acoustic pressure root means square over a relatively short duration (a few seconds or less). This global level changes over time (sliding average).

2.1.1. Acoustic pressure level

The sounds audible range is very wide and the logarithmic scale use (decibel scale) enables to represent all the change in pressure values on the same diagram. This scale is defined with respect to the auditory system detection threshold Pref = 20 μ Pascal, so as to set this threshold at 0 dB (Barbot, 2013).

$$L_P = 10\log\left(\frac{P}{P_{ref}}\right)^2 \text{ in dB(A)} \quad (1)$$

2.1.2. Equivalent sound level Leq,t

The equivalent sound level Leq,t or noise dose is regularly used as a discomfort indicator or annoyance. Indeed, in practice, there is a good correlation between this level value and the auditive embarrassment felt by an individual exposed to the noise.

The acoustic equivalent level corresponds to a noise dose received during a determined time period. It is the calculation result of the integral level sounds surveys at regular intervals (Sampling of 1, 2, …, n times per second) and for a given period T. The equation for the event-noise Leq is as follows: (Sondakh et al., 2014).

$$L_{eq} = 10\log\left[\frac{1}{T}\int_0^T\left(\frac{\widetilde{P}_{Aeff}}{\widetilde{P}_{réf}}\right)^2 dt\right] = 10\log\left[\frac{1}{T}\int_0^T 10^{\frac{L_{Pi}}{10}}dt\right] \quad (2a)$$

withLeq = the sound equivalent level; T = the duration period corresponding to the noise measurements; Lpi = the sound pressure level measured every second.

For an elementary variation dt = 1 s, the equivalent sound level equation can be written:

$$L_{eq,T} = 10\log\left[\frac{1}{T}\sum_{i=1}^{T}10^{\frac{L_{Pi}}{10}}\right] \quad (2b)$$

The sound level meter placed on the test building continuously measures the noise level. The data on one day, i.e. 24 h, can estimate the equivalent daytime sound level (LeqD) and the equivalent night sound level (LeqN). The measurement periods for these LeqD and LeqN levels correspond respectively to (06 h–22 h) and (22 h–06 h).

In weighting A, the measurement hypothesis equation can thus write: (Sondakh et al., 2014).

$$L_{AeqD} = 10\log\left[\frac{1}{16}\sum_{i=1}^{16}10^{\frac{L_{Pi}}{10}}\right] \quad (3)$$

$$L_{AeqN} = 10\log\left[\frac{1}{8}\sum_{i=1}^{8}10^{\frac{L_{Pi}}{10}}\right] \quad (4)$$

Such data allow us to estimate the average noise equivalent level (day-night) denoted L_{DN} around the airport zone.

The fundamental relationship between LDN, LAeqD and LAeqN for the perception of noise close to the airport can be described according to the following equation:

$$L_{DN} = 10\log\left[\frac{1}{24}\left(15\times 10^{\frac{L_{AeqD}}{10}} + 90\times 10^{\frac{L_{AeqN}}{10}}\right)\right] \quad (5)$$

The Day-Night Noise Level measurement L_{DN} is an important indicator in the assessment and management of problems related to perceived noise near airports. It correlates with the percentage of highly annoyed people (Schultz, 1978) and thus predicts the nuisance degree owed air traffic around the airport zone.

Noise sensitive zones around airports are forbidden at noise levels above 65 dB (A), but in practice lower levels can also cause problems and it cannot be considered the only limit between residential and non-residential zones (Slama et al., 2008).

2.1.3. Sound exposure level

The exposure level to noise corresponds to the noise level by the inhabitants as the aircraft passed overhead.

The residential zone over flight period T of the test building corresponds to the difference (t_2-t_1) where t_1 and t_2 are respectively the times corresponding to the intersection between the measured acoustic pressure level curve and the equation straight line (Lpmax - 10 dB (A)) representing the equivalent continuous acoustic pressure level. (See Fig. 1).

The weighted equivalent sound level A denoted LAeq,T is obtained over the time interval T by the following relation (Sondakh et al., 2014):

$$L_{Aeq,T} = 10\log\left[\frac{1}{T}\sum_{i=t_1}^{t_2}10^{\frac{L_{Pi}(t)}{10}}\right] \quad (6)$$

With regard to non-stationary noises, the Sound Exposure Level (SEL) received during the acoustic event total duration is defined as follows:

$$SEL = L_{Aeq,T} + 10\log(T) \quad (7)$$

The SEL noise exposure level incorporates both the noise level and the time during which the noise is present. It is defined as the constant level for 1 s having the same acoustic energy as the original sound perceived during a given duration. This acoustic indicator is often used to quantify a simple event sound energy (an aircraft passage) and to compare the sound events from a single source. The equivalent sound level (LAeq,T) and Sound Exposure Level (SEL) are considered as complementary standards at the LDN level to simulate acoustic noise near the airport (Dinato and Schaal, 2014). The SEL, LAeq and Lmax levels are directly used indicators to measure the impact of aircraft noise on residential areas surrounding the airport (Carvalho Junior et al., 2012).

2.2. The building acoustic performance

Building acoustics is the Physical Sciences field that studies the constructions acoustic performance and physical, psychological problems related to the noise emission, propagation and reception. Fundamentally, improving window tightness requires designing the window frame to have an impermeable structure. The windows and bays are the most critical facade elements from an acoustic point of view (Park and Kim, 2015).

Their effectiveness depends on:

- Airtightness;
- The glazing quality;
- The joinery and the work type.

The acoustic building reduction index with doors and windows that are closed in regard to aircraft noise.

In order to illustrate the acoustic attenuation of the building walls, in-situ measurements are carried out.

These measurements involve recording in the test building for a given period simultaneously the noise levels outside and inside the building exposed to air traffic noise. The inside measurements are made in bedrooms with doors and windows closed. The elementary acoustic pressure levels were continuously recorded at various points throughout the measurement period.

The difference between the outside noise level and the inside noise level is then calculated for each identified aircraft passage. This difference represents the local weakening global index regarded to a given sound atmosphere. The calculated index gives us an idea of the test building walls acoustic performance and the comfort level felt inside the houses.

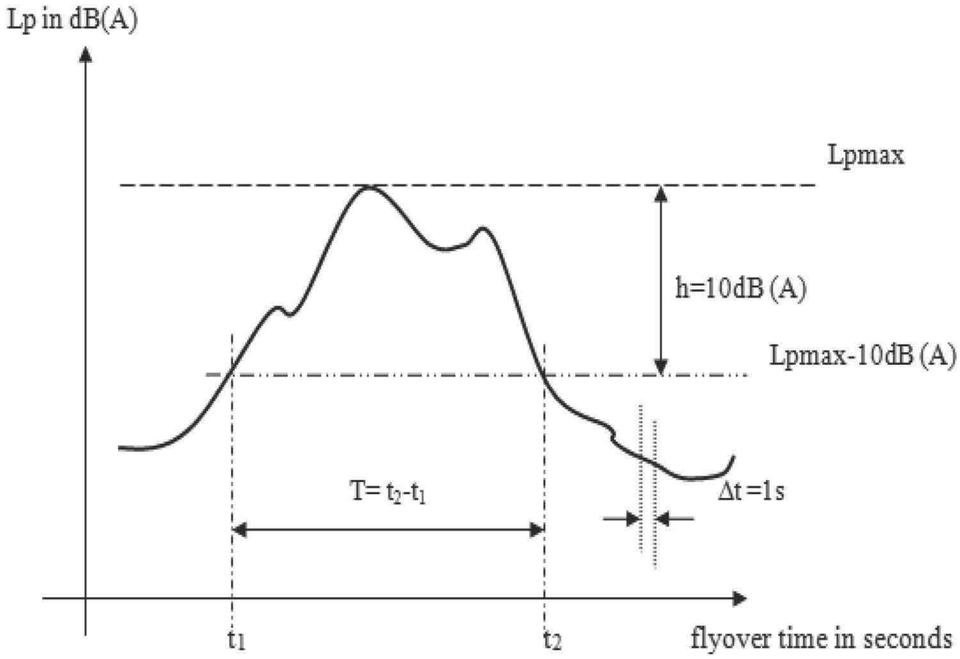

Fig. 1. The sound level evolution perceived during the airplane passage.

The weakening acoustic index R characterizes the wall ability to attenuate noise transmission. It is measured in the laboratory in the absence of all lateral transmissions. It is expressed in dB and is obtained by the following formula:

$$R = 10\log\frac{1}{\tau} \tag{8}$$

With τ the transmittance of the wall obtained by the formula:

$$\tau = \frac{W_t}{W_i} \tag{9}$$

Wt: the power radiated by the wall (or transmitted power) per unit area (w/m^2).Wi: the incident power exciting the wall per unit area. The higher the R-index, the more acoustically insulating the wall is (Brutel-Vuilmet, 2005).

2.2.1. Standardized acoustic insulation DnT

For each frequency band, the corrective factor is defined with respect to the reference reverberation time T_0. T_0 is set to 0.5 s according to the standard UNE-EN ISO 140-5 for in-situ measurements of air sound insulation for facade elements and inhabitant building facades: (Pérez et al., 2016)

$$D_{nT} = L_1 - L_2 + 10\log\frac{T}{T_0} \quad \textit{with} \;\; T_0 = 0,\, 5\textit{seconde} \tag{10}$$

2.2.2. Weighted standardized acoustic insulation

The local insulation is evaluated according to the acoustic insulation DnT expressed in dB (A) and in relation to a pink noise or in relation to a road noise.

Pink noise is the reference to characterize the qualities of building structures: walls, floors, facades, joinery, roof, etc. For increasing frequencies, the levels are decreasing at 3 dB/octave rate. A road noise is a normalized noise. It is a reference to the noise of road and rail traffic. Its spectrum is enriched in low frequencies and impoverished in highs in relation to a pink noise. For insulation between two premises, the weighted is symbolized by DnT,A (Pérez et al., 2016). For the insulation towards the external space, the weighted index is symbolized by DnT,A.tr. The transition from these indices to the single index DnT,w expressed in dB is obtained by using two corrective terms (C and Ctr):

$$\textit{For a pink noise}, \quad \textit{we have}: \quad D_{nT,A} = D_{nT,w} + C \tag{11}$$

$$\textit{For road noise}, \quad \textit{we have}: \quad D_{nT,tr} = D_{nT,w} + C_{tr} \tag{12}$$

3. Adopted methodology

The adopted methodology is based on obtaining information through the steps shown below (Fig. 2).

- Field visits
- Field investigations
- Acoustical measurements in-situ
- Data analysis and risks assessment
- Information capitalization and extraction
- Results restitution

For a relevant assessment of the inhabitants' annoyance indicators and the buildings acoustic performance in Bamako airport zone, we focused on two types of assessment (subjective assessment and objective assessment).

The subjective evaluation, in the form of questionnaires and interviews, was carried among residents and building construction stakeholders.

The objective evaluation is based on the acoustic data measured inside and outside the test building.

Extraction and processing of information is carried out using the evaluation tool illustrated in Fig. 2.

3.1. Field visits

The buildings for surveys and field measurements choice concerns the airport zones buildings. The already inhabited buildings and new construction sites are interesting for experience feedback on building constructions and renovation works. The various phases of field visits are organized to record information and data on acoustic comforts through observations, acoustical measurements and interviews with the various actors (the client, the project manager, the client or the user).

3.1.1. Field investigations

The subjective evaluation is carried out in the form of interviews and questionnaires, aimed respectively addressed to construction actors and building users.

The questionnaire (questions/answers) is addressed to the airport zone building inhabitants to identify their discomfort due to noise nuisance. The questions rest on aspects related to their needs, behaviors in the building, their reasons for living in such a place, their embarrassments, their judgments of the place life quality, etc.

3.1.2. Acoustical measurements in-situ

The in-situ background noise measurements purpose inside the building is to provide an objective assessment of the building acoustic performance and the external noise impact on the sound comfort in building rooms. The measurement stage is to position sensors (sound level meters) at the building different locations in order to measure the acoustic pressure level inside and outside the test building premises with doors and windows closed. Data from these three phases of field visits are capitalized for analysis.

3.1.3. Data analysis and risks assessment

For acoustic performance in airport buildings, the actors involved in the various phases of construction must work in synergy to ensure harmony between the building and its environment. A construction project therefore requires a better knowledge or mastery of the estate from each actor. However, a certain number of individual or collective practices can cause non-quality or risk performance factors and influence the risk development. The problem is how technicians and project managers work to prevent risks and propose appropriate solutions. Risks management depends on the experts' ability to anticipate risks in order to reduce the uncertainty probability and propose remedial solutions. Risks assessment and management require understanding and consensus among different stakeholders on the risk analysis phenomena. In this article, we present an acoustic performance risk evaluation study in building zones of airports. This study purpose is to identify non-quality or performance factors in order to improve the life quality and the users' peace. It enables us to improve the construction actors understanding of risk analysis notions through:

- Actors' knowledge identification and updating;
- Judgment knowledge reinforcement of affected probabilities;
- Recent knowledge of low-probability and high-impact risk events;
- Possible anticipation and evaluation of surprises.

To do this, the assessing process of acoustic performance risk in airport buildings requires two analysts' groups of risks; noted group 1 and group 2 (see Fig. 3). In this study, the Group 1 is the group whose members participated in the building construction project. Group 2 ignores the different planning for a construction project steps and has an impartial reflection. It must study the project from a new angle with a critical mind in order to better identify the different risk aspects that the Group 1 had misunderstood or estimated.

The acoustic performance risk assessing process in the experimental building is carried out in three phases.

Phase 1: Group 1 proceeds to standardized risks assessments, risk analysis while describing risks as a function of (P_0, C_0, G_0, M_0) (Aven, 2013).

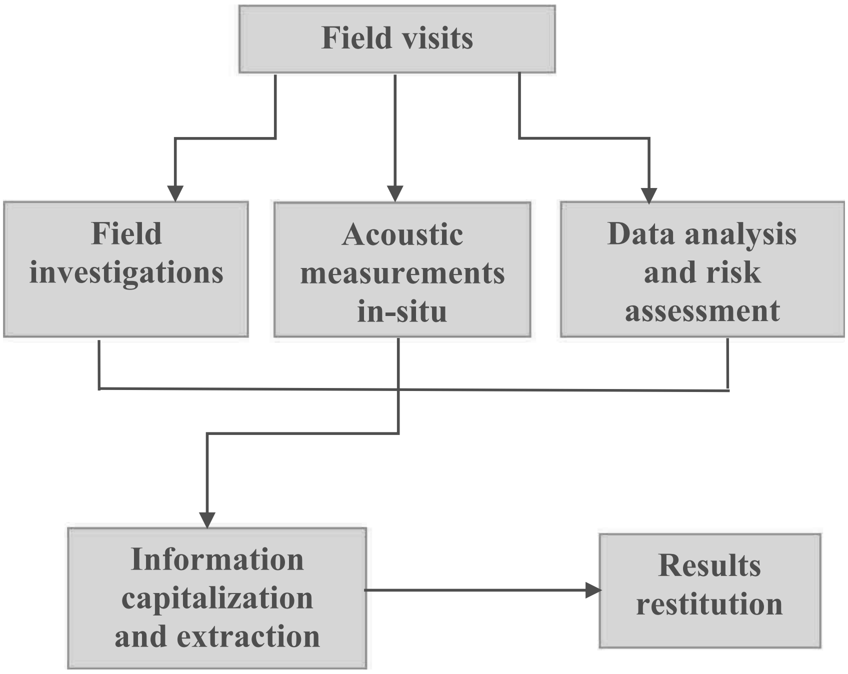

Fig. 2. The flowchart of the proposed methodology.

The terms P_0 and C_0 are respectively the event probability and the identified specific criticality level in the analysis, G_0 is the description of P_0 and C_0 uncertainty severity measurement and M_0 is the domain mastery level of construction actors or the base knowledge level (hypothesis, data and information, relevant opinions, probability models and expert judgments). The Group 1 carries out the project evaluation in the form of self-evaluation while justifying the knowledge strength or construction actors M_0 domain mastery.

Phase 2: Group 2 plays the judge role. It evaluates the risk description result (P_0, C_0, G_0, M_0) made by Group 1 from the adjusted risk argued models (P_1, C_1, G_1, M_1). Its judgment relies on the Group 1 domain mastery level through following questions verification:

- Do hold hypotheses represent significant simplifications?
- Are the information and data reliable, existing and relevant?
- Do the expert opinions constitute a consensus?
- Are the phenomena involved understood?
- Are the models available?
- Are the predictions coherent? (Flage and Aven, 2009).

In the building construction domain, this verification is based on the field knowledge, the applied techniques relevance and the appropriate choice of materials.

Phase 3: By joint agreement, the two teams provide their report by giving a detailed description of risks. This provides a risk discernment database and a strong support for decision-making. The various construction actors acquired knowledge can motivate comments on the gravity G uncertainty judgments and can constitute important aspects of the domain basic knowledge M.

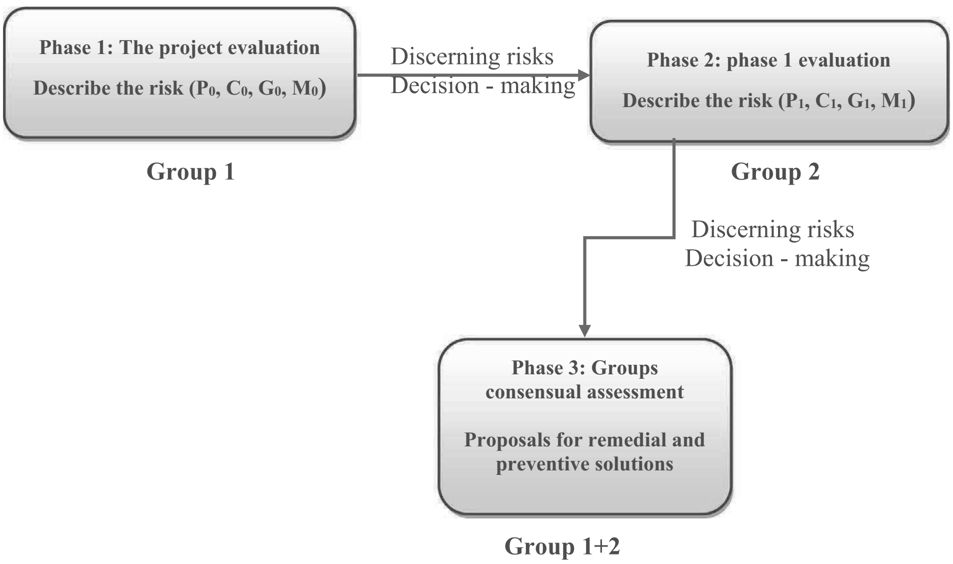

Fig. 3. The risk assessment approach with three phases.

3.2. *Information capitalization and extraction*

The data collection allows us to inform an elaborated criticality matrix for the circumstance. The criticality matrix is a data mining tool in order to determine and organize into a hierarchy non-quality or performance risks factors. The criticality matrix architecture drew its inspiration from data knowledge extraction principle. The surveys and measurements results make it possible to organize into a hierarchy the risk performance factors for a better management of the life quality through the building's acoustic comfort. Criticality level C of a risk is defined in terms of the probability of their occurrence and the gravity of their consequences G and mastery of the field M. The risk assessment and analysis of the various scenarios is made with the classic formula below:

$$C = P*G*M$$

where C: Criticality level, P: Probability of occurrence, G: Gravity of the possible consequences, M: Mastery of the field.

The criterion "Probability" is relating to the degree of relevance of the techniques and the construction materials used.

The criterion "Gravity" is relating to the functioning and the consequences of cascading impacts.

The criterion "Mastery of the field" can balance the risk level assessment. It depends on the designers' competence and must take into account:

- The degree of relevance of the choice considered (techniques and materials used)
- The level of failure delectability (e.g. wall tightness level),
- human means and intervention capabilities (ex: technicians' knowledge level),

The three criteria are qualified and quantified according to Table 1.

Criticality level C aims to assess and prevent risks. Four risk assessment criticality levels are defined (Low/Medium/Strong/Very strong), respectively associated with a color code (green, orange, red, black) (Table 2).

Risk analysis aims to identify different non-quality and disorders in order to facilitate the criticality levels reduction through adequate practices and preventive solutions.

3.3. *Results restitution*

The evaluation results are organized into a hierarchy and capitalized according to their importance and their criticality level. Corrective solutions (appropriate techniques and good practices) are recommended. The practical knowledge resulting from the various stages of this study is therefore elaborated to create conditions for the improvement of life quality of the target population by means of increasing the acoustic comfort in the buildings located in airport areas.

Table 1
The risk matrix.

Probability		Gravity		Domain risk mastery	
Nature	Level	Nature	Level	Nature	Level
Strong	*4*	Catastrophic	*4*		
Medium	*3*	Serious	*3*	Strong	*0,6*
Low	*2*	Tolerable	*2*	Medium	*0,8*
Very weak	*1*	Minor	*1*	Low	*1*

Table 2
Criticality matrix.

Color code	Nature	Criticality level (C)
	Low	$C < 4$
	Medium	$6 \le C \le 9$
	Strong	$9 < C < 12$
	Very strong	$C \ge 12$

4. Case study: acoustic performance study of a building zone at Bamako airport

4.1. *Case study presentation*

The experimental building is located 4 km from the airport and 700 m from the RN7 (national road 7) in Bamako Sirakoro-Senou district in commune VI.

The built area is 139.30 m^2, it has two blocks, each one contains a bedroom, a living room, two terraces and an internal toilet (see Figs. 4 and 5). Like most of the buildings in the zone, the building wall external facade is constructed with cement bricks (15 cm hollow blocks), internal walls or partition walls are constructed with blocks of 10 cm, and the roof is made of cement concrete slabs. The coating or layer mortar applied to the facades surface (inside and outside) has about 0.5 cm thickness. The openings (doors and windows) are metallic shutters without glazing. The experimental building is on a plot of 300 m^2 (15 m × 20 m). The courtyard is enclosed with 1.5 m high walls and is located to the southwest in relation to the landing and take-off runway direction.

4.2. *Case study justification*

Bamako International Airport is the largest in Mali (the main airport). It is located in commune VI in Bamako northern part at a distance of 15Km from the town center (Fig. 6).

Commune VI of Bamako is the largest in terms of area (70 Km^2) and estimated population at 545,000 people (the 2011 census).

Bamako International Airport offers direct access to travel destinations in West Africa and international and plays a key role in the region development tourism. The zone immediately surrounding is very large, called the ASECNA zone and mainly underdeveloped. In these recent years, this zone is highly coveted by real estate agencies.

The airport southern zone is the most affected by the extension with inhabited cities and in sites (Senou, Diatoula and Sirakoro districts). The experimental building is located in Sirakoro district.

In the last decade we notice, on the one hand, construction sites development within a radius of < 10 km around the airport and, on the other hand, Bamako International Airport extension welcomes capacity.

4.3. *The method analysis application and the case study risk assessment*

The study concerns the assessment and analysis of the acoustic performance risk in Bamako airport zone buildings.

The experimental building has metallic shutter doors and windows in its openings with mosquito nets screen. These types of openings are not watertight. They have a high air and noise permeability because they allow thin air streams to pass around the sunroof perimeter.

The walls building external and internal walls are respectively constructed with blocks those of 15 cm and 10 cm thicknesses. The coating thin layer applied to the different faces has 0.5 cm thickness. Field visits observations revealed some pathologies (cracks, badly filled holes, non-watertight junctions) on the building walls. Pathologies which can cause parasitic transmissions due to airtightness lack of air noise. These airtightness anomalies are certain practices results or realizations that create phonic bridges.

The analytical process and risk assessment guidelines (described in

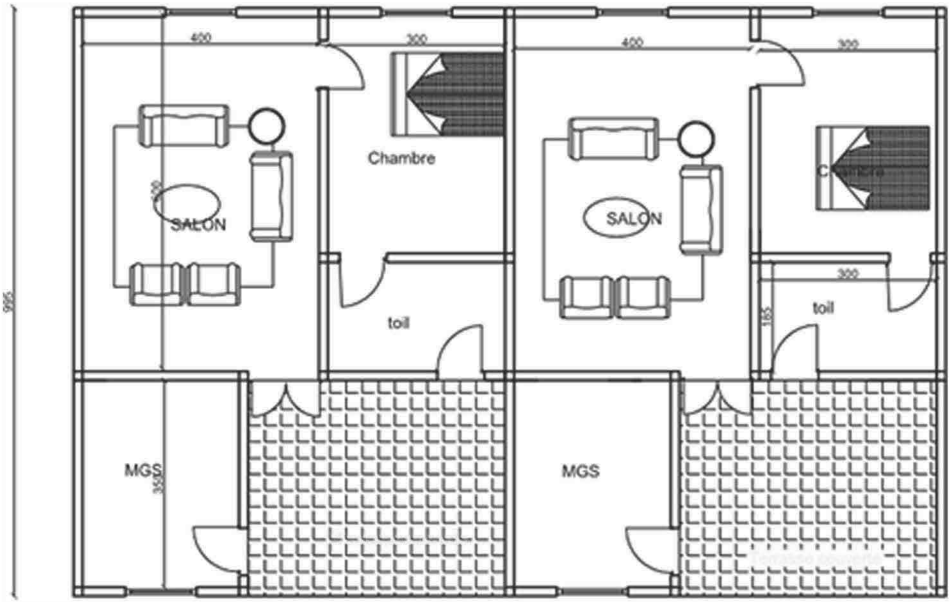

Fig. 4. The experimental building plan.

the evaluation section) recommend two groups of risk analysts (group 1 and group 2).

In the first phase, the first analyst group is the master and the technicians (electricians, acousticians, plumbers, builders, etc.). The group members consult and carry out the risk assessment associated with aircraft noises impacting indoor noises of buildings in order to decide on the precautionary and emergency measures to reduce linked risks to the identified non-quality. Sound penetrations are due to carpentry openings types and phonic bridges at the walls level (cracks or holes). The identified risks analysis linked to the different stages operation is done with risk matrix right at assigning risk probability and gravity levels (consequence).

The analysis process is composed of as follows:

- Activities planning in basic steps (for work acquisition by group members at each stage);
- Non-quality identification or risk factors for each stage;
- Probability (P_0) and consequences gravity (G_0) assessment;
- Assessment of criticality level (C_0) concerning potential threats linked to each non-quality;
- Proposals for corrective and preventive measures to threats.

This information is given from a risk criticality matrix. This makes it possible to carry out the evaluation, present risk events and organize into hierarchy compensation measures.

In this case study, the effort is focused on the risks associated with aircraft noises impacting indoor noises of buildings and this is due to the used types of openings. Such doors and windows use in airport buildings are not fortuitous in view of the fact that acoustic discomfort risks are due to air noises' infiltration. The sound discomfort risk in the building is linked to the aircraft noises impacting indoor noises of buildings through the openings' types (doors and windows). This noise propagation was not properly taken into account in the process of choosing the most appropriate insulation materials for buildings.

This scenario description of the aircraft noises impacting indoor noises of buildings; risk in the building is described by group 1 as follows:

- P_0: low probability (probability level equal to 2);
- Air noise G_0: tolerable sound penetration in the building (gravity level equal to 2);
- Domain M_0: strong mastery (risk mastery level equal to 0.6).

These indoor noises caused by diverse outdoor aircraft noises are analyzed in the studied scenario and the considered context in which actors have limited access to knowledge. This consideration can allow us to interpret the risk assessment and update the analysis according to the following criticality level formula:

$$C_0 = P_0 * G_0 * M_0 \quad \text{with} \quad P_0 = 2, \ G_0 = 2, \ M_0 = 0, 6$$

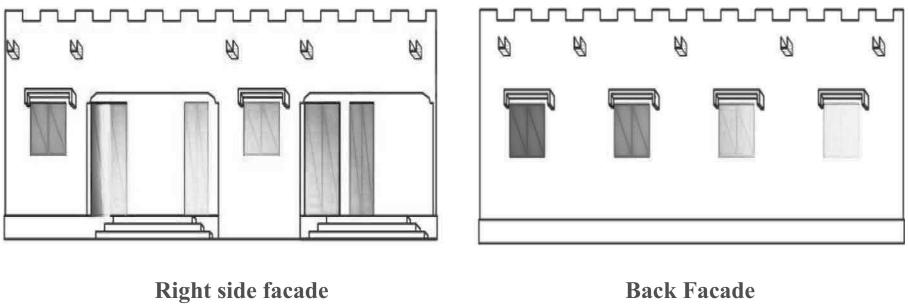

Fig. 5. The experimental building facades sights.

Fig. 6. Bamako International Airport air sight.

therefore $C_0 = 2*2*0,6 \qquad C_0 = 2,4$

The criticality level is lower than 4, in accordance with the matrix; it is assigned the green code as shown in the risk matrix above. So the risk is qualified low (Table 3).

Table 3
Low criticality level risk.

Risk	Nature	Criticality	Code
	Low	2,4	

In the second phase, Group 2 carries out an assessment of risk description done by the Group 1. The relevance and usefulness of risk description outputs is therefore a determining factor behind the strength of knowledge for a better mastery of the field by designers. Failure to take into account the noise infiltration aspect of the airport building during the operation planning by the evaluators must be due to an omission, a lack of the building construction site particularity consideration (Airport zone) or simply a risk light judgment. For presentation reasons, Group 2 considers this latter case (designers' hypothesis is less relevant), so the domain strength knowledge or mastery M_0 is judged low because fewer than one of the conditions described below by Flage and Aven (2009) are verified:

- restrained hypothesis represent major simplifications;
- Information and data are non-existent or very unreliable and irrelevant;
- Expert opinions strongly disagree;
- The involved phenomena are misunderstood;
- Models are non-existent or known/supposed to give bad predictions.

The domain mastery or designer knowledge is therefore low ($M_1 = 1$) and the catastrophic gravity uncertainty ($G_1 = 4$) and the medium probability ($P_1 = 3$).

The criticality level is obtained with the criticality level formula:

$C = P*G*M$

Table 4
Strong criticality risk level.

Risk	*Nature*	Criticality	Code
	Very strong	12	

This information allows calculating the criticality level below:

$P_1 = 3, \quad G_1 = 4, \quad M_1 = 1 \qquad C_1 = 3*4*1 \quad thus \quad C = 12$

The criticality level is equal to 12, this leads to a very strong risk and therefore it is assigned the black code (Table 4).

In the third phase, the two groups of analysts elaborate risk attached description. In this case there is a disagreement between experts' opinions (question 3 above) concerning planes noise infiltration in the building because of doors' and windows' types. Consequently, the domain strength knowledge or mastery supporting risk assessment is reduced. This leads to the low criticality level (black color in the risk matrix) and the catastrophic gravity consequences (as shown in the risk matrix above). They advocate corrective solutions in the renovation of works context for an improvement related to the acoustic and thermal comfort of the users, namely:

- The windows and doors use made of aluminum or wood with thermo-acoustic glazing and Rw (C; Ctr) high designed with flexible joints between openings and frames in order to ensure a good airtightness.
- The controlled mechanical ventilation system use (CMV) to reinforce thermal comfort.

These air and air noise airtight doors and windows can ensure natural ventilation and inside air renewal (CO_2 evacuation, pollutants, smells …) through an air intake grille equipped with:

- deflector allowing the incoming cold air to be directed first to the ceiling so that it mixes with the ambient air to minimize the inconvenience it could produce to the occupants;
- a sound absorber according to the acoustic insulation degree in relation to external noise nuisances;
- An anti-insect device (e.g. protective grilles against flies or mosquitoes …)

4.4. Field investigations and in-situ measurement

4.4.1. Field investigations

In order to estimate the buildings acoustic performance in Bamako airport zone and the inhabitants acoustic comfort level, we carried out a survey with the zone's population (subjective evaluation in the form of a questionnaire) from January 25 to February 05, 2017. The questionnaire was developed and distributed to 60 dwellings of various types (collective housing, individual housing, etc.).

The questions were on:

- Dwelling types;
- Dwelling constructions having characteristics (date, materials, etc.) that are similar to those of Bamako airport;
- Judgment on the part of the user in relation to his dwelling comfort;
- Renovation work types carried out for the building acoustic performance;
- The sound environment qualification towards the zone's air traffic according to the moments (morning, afternoon and evening) and the place in the house (inside and outside);
- Harmful effects on the quality of the users living environment.

Compared to the survey technique, we went door to door to distribute the questionnaire sheets in the various dwellings. The questionnaire was answered immediately by some users and others asked us to pass after because they wanted to answer the questions later. At the end of the survey, we were able to retrieve 54 sheets out of 60 namely 90% of the questionnaire sheets.

The results from the survey are shown in Table 5 below:

The results analysis shows us that:

- Most of the dwellings in Bamako airport zone (87% of surveyed dwellings) are collective dwellings where people live with their families;
- Bamako airport zone is an urban zone exposed to the noise of planes with strong noise nuisances observed during the night;
- Airplane noise actively participates in the degradation of the residents' health increasing stress, sleep disturbance, the children's concentration disturbance during school hours, headaches, hearing problems and depression.

4.4.2. In-situ acoustic measurements

Background noise levels inside the building measurements were made in the case study building. The purpose is to make an objective assessment of the building acoustic performance and the external noise impact on the sound comfort inside the building rooms.

The measurements were carried out using two brand sound level meters “voltcraft” meeting the European standard **EN 61 672-1** relating to sound level meter. Its class2 sound calibrator is in accordance with the standard **IEC 60942.** The measurements were carried out over a period of about a month (from February 10 to March 07, 2017). In order to record the airplanes sound pressure is level so as to keep tracks and to realize the noise atmosphere inside the building, the sensors were calibrated on the automatic range included between 30 and 130 dB. Sound level meter is put inside and outside the building in order to measure acoustic pressure levels. These measurements are used to estimate equivalent sound levels and aircraft noise exposure in order to get an idea of the building walls acoustic performance. To avoid possible disturbance to the measurements due to reflection of sound waves, the sound level meter is placed at 2 m position apart from the building internal and external surface and at 2.5 m height above the floor. The sound level meter measurement signal frequency is evaluated with the characteristic curve A. The filter is activated in the display dB (A).

4.4.3. The equivalent sound level and the aircraft noise exposure level

Living in airports zones results exposure to noise pollution, which is undoubtedly a major nuisance and a poor life quality for the exposed populations. The purpose of this section is to contribute to the noise pollution assessment in order to facilitate decision-making regarding pollution control and lands and buildings efficient management around Bamako airport. To do this, we calculate the equivalent day-night noise

Table 5
Survey results.

Questions	Answers	Detailed answers
Q.1: Dwelling type	A.1: three (03) individual dwellings	Apartment-sharing
	A.2: Forty-seven (47) collective dwellings	Family life
	A.3: Four (04) other dwelling types	Two (02) restaurants, one (01) kindergarten and one (01) clinic.
Q.2: the dwelling existence in relation to the airport date.	A.2.1: 15% dwellings preceded the airport.	A.2.1.1: 100% of users consider the dwelling acoustic performance as low. A.2.1.2: 15% of the users attempted renovation work, 65% did not know that it was possible to improve the building acoustic performance, 20% knew, but say that they have not the means for this work.
	A.2.2: 85% found the airport built.	A.2.2.1: 100% of users say they have not taken into account the acoustic performance in construction. A.2.1.2.: 86% didn't know the aircraft discomfort, 14% did not answer this question.
Q.3: Airplanes traffic frequency levels around the house.	High (for 25% of surveyed), Medium (for 42% of surveyed), Low (33% of surveyed)	
Q.4: Sound environment due to airplanes	A.4.1: Inside the building	Morning (Quiet (46%), noisy (45%), very noisy (9%)) Afternoon (Quiet) (43%), noisy (47%), very noisy (11%) Night (Quiet) (21%), noisy (59%), very noisy (20%)
	A.4.2: Outside the building	Morning (Quiet) (86%), noisy (12%), very noisy (2%) Afternoon (Quiet) (63%), noisy (21%), very noisy (16%) Night (Quiet) (58%), noisy (31%), very noisy (11%)
Q.5: The noise harmful effects on the quality of your living environment	A.5: Sleep disturbance (37%), Stress (19%), hearing problems (23%), headaches (11%), hearing problems (14%)	

Table 6
The results of calculation levels with LAeqD, LAeqN and L_{DN} in dB (A).

The values of the different levels in dB (A)	From 23/02/2017	From 04/03/2017
L_{AeqD}	67,5 dB(A)	65,6 dB(A)
L_{AeqN}	62,4 dB(A)	60,5 dB(A)
L_{DN}	70,01 dB(A)	68,1 dB(A)

level LDN (LAeqD, LAeqN) and the noise exposure level during aircraft passages above the test building housing zone, based on the data measured on February 23, 2017, and on March 4, 2017. The time required for the LAeqD and LAeqN calculations are respectively (6 h to 22 h) and (22 h to 6 h) (Table 6).

From Eqs. (3), (4) and (5), the calculation results are recorded in the table above.

From these results, it can be seen that:

- Outside the dwellings during the day, the LAeqD indicator oscillates between 67.5 and 65.6 dB (A). These values far exceed 55 dB (A) a great discomfort inside the houses sensation threshold.
- Outside the dwellings during the night, the LAeqN indicator varies between 62.4 and 60.5 dB (A). These values are > 40 dB (A) the strong sleep threshold disturbance (Slama et al., 2008).
- The estimated L_{DN} level is between 70.01 and 68.1 dB (A), also exceeding very clearly the level of 52.6 dB (A) level which corresponds to the upper limit for strictly urban residential zones in NBR 10151;
- L_{DN} levels are all above 65 dB (A), which tell us that the test building zones are sensitive zones to noise generated by Bamako airport air traffic (Slama et al., 2008).

4.4.4. Aircraft noise exposure levels

In order to get an idea of exposure levels due to aircraft noise, we have shown in Figs. 7 and 8 sound pressure levels with their evolution recorded during the two aircraft passages above the test building. These figures relate to the data measured on February 23, 2017, respectively, between (10 h 21 min 10 s and 10 h 22 min 41 s) and (23 h 39 min 30 s and 23 h 40 min 54 s).

The data used correspond to the sound pressure levels measured outside the building.

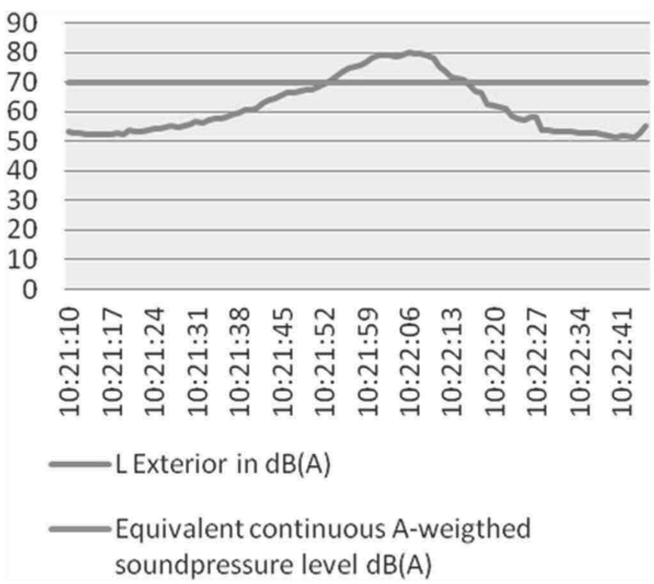

Fig. 7. Sound pressure levels evolution related to the airplane passage between 10 h 21 min 10 s and 10 h 22 min 41 s.

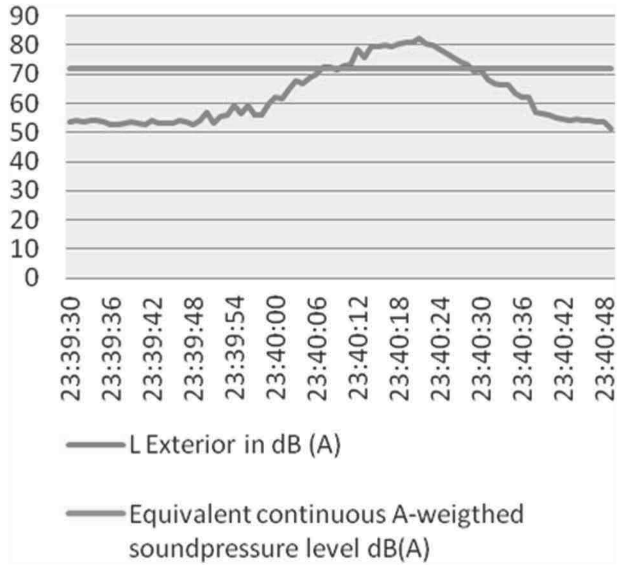

Fig. 8. Sound pressure levels evolution related to the airplane passage between 23 h 39 min 30 s and 23 h 40 min 48 s.

The equivalent sound level LAeq, within a period T and the exposure level to aircraft SEL noise during their over flights on the test building residential zone are determined by the following formulas:

$$L_{Aeq,T} = 10\log\left[\frac{1}{T}\sum_{i=t_1}^{t_2} 10^{\frac{Lpi(t)}{10}}\right]$$

$$SEL = L_{Aeq,T} + 10\,log\,(T)$$

where T = t_2 - t_1 is the measurement period in seconds, t_1 and t_2 are times corresponding to the intersection between the measured sound pressure level curve (blue curve) and the equivalent continuous sound pressure level (red line) in Figs. 7 and 8, the sampling time is 1 s (dt = 1 s), Lpi (t) is the acoustic pressure level measured for each time sample between t_1 and t_2.

For Fig. 7, the observed maximum level LAmax is 79.9 dB (A) at 10 h 22 min 06 s. The equivalent continuous sound pressure level (LAmax -10 dBA) is 69.9 dB (A).

The intersection points correspond to the times t_1 = 10 h 21 min 54 s and t_2 = 10 h 22 min 14 s, and the period T = 20 s.

For Fig. 8, the observed maximum level LAmax is 82.1 dBA at 20 h 40 min 21 s.

The equivalent continuous sound pressure level (LAmax -10 dBA) is 72.1 dBA, which leads to the intersection points of time t_1 = 23 h 40 min 09 s and t_2 = 23 h 40 min 30 s, so the period T = 21 s.

The equivalent sound level LAeqT and the exposure level corresponding to the SEL aircraft noise value are recorded in the following Table 7:

The study area is within a radius of 10 km around the Bamako-Senou International Airport (see Section 4).

The over flight of the residential area of the test building being considered as a single transient phenomenon, we take into account the level of noise exposure (SEL) and the equivalent sound level LAeq, T corresponding to the over flight period T.

In accordance with European regulations, 10 to 12 km of concentric

Table 7
Calculation results of these LAeqT and SEL levels in dB (A).

	$L_{Aeq,T}$ in dB(A)	SEL in dB(A)
Fig. 7 (LAmax = 79,9 dB(A); T = 20 s)	77, 35	90, 36
Fig. 8 (LAmax = 82,1 dB(A); T = 21 s)	78, 49	91, 17

airport zones must be subjected to a noise level representative of aircraft noise (SEL noise level) not exceeding 100 to 90 dB (A), respectively Day and 80 to 90 dB (A) during the night outside the dwellings. The equivalent noise level LAeq, with T corresponding to the overall energy average specific to the noise perceived during the period T of aircraft passages must not exceed the threshold values of 60 to 64 dB (A) during the day and 50 to 55 dB (A) During the night (source: http://www.leefmilieubrussel.be/Templates/download/19990527_agb_LutteBruit_TraficAerien.pdf? langtype = 2060 Last accessed on *04/08/2017*).

The results obtained in Table 7 show that:

- The value 90.36 dB (A) indicating SEL is in the range of threshold values for the day;
- The value 91.17 dB (A) indicating SEL exceeds slightly the threshold value of the night;
- The values 77.35 dB (A) and 78.49 dB (A) indicating respectively the level LAeq, T day and night relative to the passage of the aircraft exceed very well thresholds.

According to these results, we can say that within a radius of 10 km around the International Airport of Bamako, the noise pollution linked to the over flights of the aircraft is likely to alter the habitability and the quality of life in this zone.

The main purpose of these assessments is to assist decision makers or local authorities in making decisions about the land use efficient management and the limitation of Bamako airport zone in order to ensure the acoustic comfort of inhabitants and prevent problems related to noise perceived near airports.

4.4.5. The test building acoustic performance

The test building described in Section 4 is located in Bamako airport zone. To estimate the test building facade elements acoustic performance level, a determination of the test building acoustic attenuation was carried out on the “in situ” acoustic measurements basis.

These measures consist of raising the noise levels outside and inside the exposed building to air traffic noise. The inside measures are made in building rooms with closed doors and windows.

The extracted data measured on 23/02/2017 and 04/03/2017 at the noisiest moments (airplane flight above the test building) are shown in Figs. 9 and 10. These representations bring out the intensity loss of the observed sound level.

The magnitude ΔL in dB is the difference between the sound pressure level measured outside the building and that measured inside.

$\Delta L = L_{ext} - L_{int}$

The attenuation of a building's walls sound level intensity is proportional to the difference ΔL.

In the laboratory, this difference in acoustic pressure level corresponds weakening index R of the building exterior walls. It represents a material ability to prevent the air sounds' transmission with ΔL value, thus, it allows us to know if the building wall is performing yes or no (the more ΔL has a high value, the more the walls are performing).

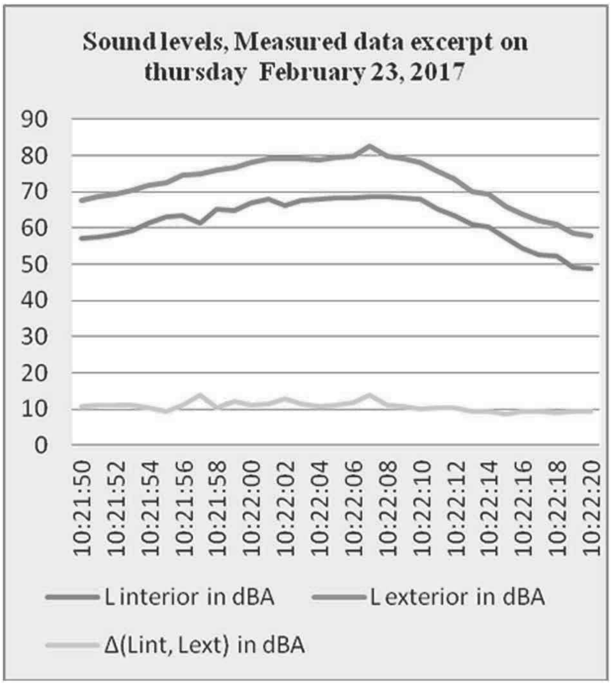

Fig. 9. Graphic illustration of the difference between the external sound pressure level and the internal sound pressure level of the building on 23/02/2017.

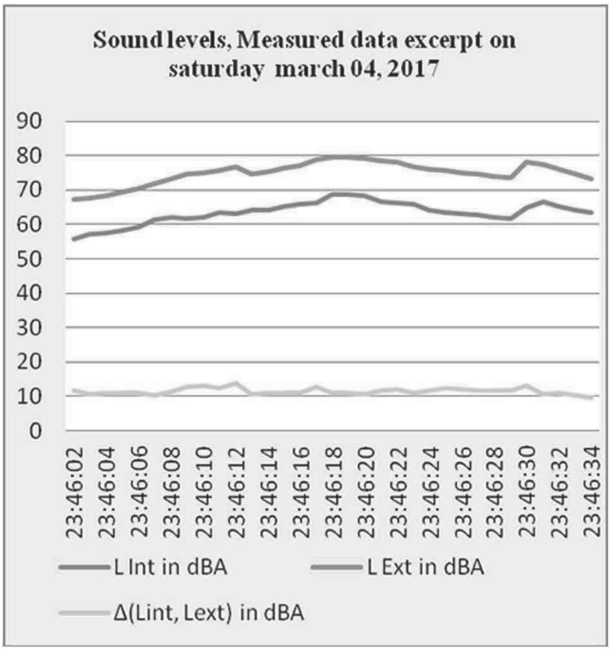

Fig. 10. Graphical illustration of the difference between the external sound pressure level and the internal sound pressure level of the building on 04/03/2017.

5. Results

The above graph values show us that the walls intensity level attenuation (the weakening index) is the order of (9.8 and 13.9 dB (A)) and (9.6 and 13.7 dB (A)) respectively on 23/02/2017 and 04/03/2017. Very low values attest that the walls do not have adequate acoustic performance for an airport building. For example, when passing aircraft, it is generally observed that the sound pressure level measured inside the building exceeds 50 dB (A) (acoustic comfort level threshold value relating to sleep in a room). Considering most of Bamako airport zone buildings are built under the same conditions (lack of building standards or regulations), we can therefore consider that acoustic comfort in buildings is not guaranteed. Given the air traffic importance, we can estimate that the inhabitants of Bamako airport zone are exposed to noise nuisance. These results include among others:

- Used opening types in the buildings (metal shutters doors and windows with non or single glazing)
- Low insulation of the building walls (walls, ceiling, floor, etc.) made with a coated plaster thin layer of cement;
- Sound bridges or holes in the walls (embedded electrical outlets);

- The building's type usages linked to climatic conditions (opened windows and doors for ventilation during warn periods).

To improve the building acoustic performance in order to guarantee the users' acoustic comfort, we suggest rehabilitation or renovation works while adopting the following corrective solutions:

- Reinforcement of the walls insulation, for example the roof by placing inside a soft and thick insulation (mineral wool) plated with a dense material (phonic plaster);
- Rooms interior dressing in plasterboard attached to independent metallic frame;
- Exterior dressing facade elements by cladding wood, painted or coated panels (DGAC, 2006);
- The obstruction of the direct transmissions through the anti-noise paint put on an sound-absorbing layer (for a reduction from 3 to 15 dB according to the frequencies) (DGAC, 2006);
- Use of windowless joinery (doors and windows with joints);
- Change of window glazing with the asymmetrical acoustic double glazing from type x-y-z (glass thickness x in millimeters, air blade thickness y in millimeters, glass thickness z in millimeters) and caulking the frame;
- The use of glazing from type "acoustic laminated" reinforcing the performance. (30 to 40 dB acoustic attenuation);
- Caulk to best orifices retrieval from the works of the building electrical installations and plumbing.

The developed countries airport noise pollution management policy:

The policy and legislation on the air traffic noise management refer to the standards which are in general based on the noise pollution indicators (e.g. LND, LAeqD and LAeqN) and noise simulation levels in the areas close to airports (Dinato and Schaal, 2014).

For example, the European Environment Agency study (AEE, 2010) reveals that 27% of the people "are very bothered" above the threshold of 55 dB(A) because of the aircraft noise. In addition, this can become irritating over time and cause a very adverse effect on people's quality of life (Boegli et al., 2006). Other example, the European Commission report (Official Journal of the European Union, 2012) shows that an increase of the sound level at equivalent-night LAeqN all 5 dB(A) can increase by 1,5 times the sleep disturbance percentage, by 5% in the level LAeqN = 45 dB(A) (on the building facades) until 12% in LAeqN = 55 dB(A). It is so much obvious that the sleep disturbance depends on the facade soundproofing value and can be minimized by an appropriate facade design. So, the measured outside levels of the building (LAeq and\or Lmax) must be used for the specification of sound insulation properties airborne facades in order to reduce the impact of the aircraft noise (Jagniatinskis et al., 2016).

The International Civil Aviation Organization (ICAO) has provided many studies results based on aircraft noise management called "balanced" approach (Ganic et al., 2015) showing that some developed countries airports (such as Heathrow in London, Schiphol in Amsterdam, Zurich in Kloten, Roissy-Charles-de-Gaulle in Paris and Frankfurt am Main in Frankfurt) have so far implemented air traffic numerous noise reduction measures. Policies adopted in noise management and control do not target single solutions, but use any combination of solutions can be envisaged depending on the most appropriate option to address the causes of problems (Netjasov, 2012). These policies revolve around the following actions:

- Land use planning and management around airports;
- Noise-abatement exploitation procedures;
- Specific time operating restrictions.

These different actions are based on a thoughtful urban plan and the legal legislative laws. They recommend to airport administrators and infrastructure construction actors the following measures:

- To apply rigorously the Noise Exposure Plan (NEP) relating to noise determining around the airport in order to alert existing and future owners to the possible sounds impacts from a nearby airport. These measures also prevent or discourage the incompatible property development in airport zones without regulatory approvals and documentations, for example, the individual houses construction in the high sound nuisance zone will have to be forbidden (Ganic et al., 2015);
- To require that the Urbanism Premises Plans (UPP) and the municipal maps are established, in sectors submitted to the air nuisances, only after elaborating a Territorial Coherence Scheme (TCOS) which will have to resume and specify in a rigorous way the building constraints sectors;
- To fix sound insulation standards reinforced in the zones which, even though not forbidden to the construction, are submitted to nuisances because of regular overflying (DGAC, 2006);
- To encourage acoustic insulation for the buildings (e.g. Residences and Public Buildings) through adequate technical insulations of incompatible doors, windows and probably air conditioning units for constructions located in the airport's vicinity.
- To acquire lands or zones compatible to noise or relocate all the occupants who are within sensitive noise levels (Netjasov, 2012 and Boeing, 2014);
- To comply the laws relating to the Aviation Easement Acts granting the right to fly over housing areas, even if the practice causes damage, inconvenience, or the of falling property values. Such law compliance generally prevents occupants to not build or cultivate anything in a specified zone (Ganic et al., 2015);
- To orient the runways so that the planes overfly as little as possible buildings and particularly the dwellings;
- To prevent that future urbanization do not contradict or annihilate the previous choices.

6. Discussions

The air traffic growth in the big cities generates health problems, inconvenience and damage to the airport buildings inhabitants' life quality. For users' comfort and life quality improvement, it is important to focus on the good management of the noise pollution and airport infrastructure and buildings acoustic efficiency. To do this, various studies are envisaged (acoustic performance risks and in-situ acoustic measurements analysis and evaluation). Acoustic measurements inside the building require quality instruments (sound level meter) and also correspond to measurement requirements and standards. In the building acoustic domain, there are several standards, each of which requires a specific measuring device type. Sometimes, a device corresponds to standard requirements, but these operating principles and conditions can be a handicap for various reasons. For example, measurement of on-the-ground realities (climatic conditions, distance and safety), devices with a low level of autonomy (batteries periodic replacement needs, low recording capacity, etc.), risks of damage to the device used in the flying area (measurement in full construction site). In an isolated zone context, mobile equipment and long autonomy are needed, contrary to those that require computer permanent connection for data recording. In related to the choice, online research (the internet) must be done to compare devices characteristics (measurements reliability, data accessibility, etc.) and obtain the experts, manufacturers opinions, etc.

Given the measurement of ground realities where the internet connection rate and the electricity coverage are very low, we stressed on the measuring device autonomy (autonomy of batteries supplies autonomy and the recording capacity). Two certified digital sound level meters **SL-451 to EN 61672-1** norm class 2 has been chosen for the pressure measurement levels in the building outside and inside. These devices strong spot are their measurement range from 30 to 130 dB (A/C evaluation), their accuracy (± 1.4 dB, 1 kHz), then adjustable time (fast and long) and then operation with batteries or with a supply block. The sound level meter **SL-451** is equipped with a data logger and a USB interface. Thanks to its solid casing with rubber protection injected, they are also suitable for difficult conditions use. The device has software and extension to the microphone with a measuring range automatic selection function. An integrated data logger allows us to record as far as 32,000 measurements that can be read later and operated on the PC with the supplied software. Thanks to the removable microphone and the extension with 3-meter extension cable it is possible to carry out, measurements even in the most difficult places. The data stemming from this measurement phase are treated with the software. These measurement results and those obtained during acoustic performance with the evaluation and analysis of associated risks have advocated corrective solutions or good practices in the new construction context and building renovation projects in airport zones.

7. Conclusion and perspectives

This article study deals with the acoustic performance with the risk assessment of buildings in the airport zones. The methodological approach is based on fields' visits in the form of field investigations and acoustic measurements sessions inside the building. These investigations are carried out in the form of questionnaires addressed to the inhabitants and interviews with various experts (project managers and technicians) involved in construction projects and acoustic pressure measures outside and inside the building test. These different stages allowed obtaining:

- Measurements of the perceived sound intensity within buildings;
- Indicators of discomfort, pollution management and land use around the airport;
- Opinions of the inhabitants of the area in relation to their environment and quality of life;
- Practices and techniques in adequacy at the construction actors level;
- Users and construction actor difficulties and needs.

The case study concerned a building in Bamako airport zone. The information analysis obtained necessitated different sound levels calculation LAeqD, LAeqN, LDN and the aircraft noise exposure (SEL) level.

The building acoustic performance risks factors, namely the openings' types (doors and windows), airtightness faults (cracks and holes on the internal walls due to electrical and plumbing installations) and the insulation failures of internal walls that have been identified.

For future building projects and renovations, the indicator values such as the equivalent noise level and the airplane exposure level serve as indicators to construction indicators and decision makers to the judicious use of Bamako airport exposed zones to noise nuisances. Corrective solutions relating to identified disorders and non-quality were recommended.

The capitalized knowledge associated with the captured good practice allows us to ensure harmony between the airport building and its environment (protection against noise nuisances, atmospheric emissions from airplanes, and the appropriate use of materials). Thus, this provides some new thinking in order to offer certain opportunities to improve acoustic comfort and inhabitants' quality of life.

To more consolidate this study results, data from a simulation study of computer software is envisaged.

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