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RATING NOISE LEVEL AS ENVIRONMENTAL NOISE INDICATOR

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Abstract. *The noise sources of different characteristics dominate in the structure of formed acoustical load of environment and bring to the usage of different indicators for the description and estimation of acoustical load. The aim of choosing the corresponding noise indicator among different alternatives is reduction of large volume of information to a simple indicator assembly that is easy to handle, but still meaningful. The national regulations in this area define the methods of measurement and estimation of environmental noise level using the rating noise level. Starting from the used methods in different countries of Europe, the methods defined by national regulations and long-standing experiences in environmental noise measurement, the authors give an algorithmic scheme of rating noise level determination procedure.*

Key words: *rating noise level, noise indicator, noise assesment*

1. INTRODUCTION

Despite of many researches of evaluations on human population exposure to noise level experiences of many explorers shows that it is very difficult to quantify noise effects, because of:

– different noise level tolerance of the population;
– different types of environmental noise sources;
– different methods for obtaining noise exposure information, and
– different noise indicators.

According to the estimations from the European Community document called "Green Paper" [2], 20% of the population (or 80 million people) is exposed to noise levels that cause sleeping disturbances, population annoyance and negative influence on human health. Beside that, 170 million of citizens of Europe (or 42%) live in areas where noise levels cause serious annoyance during the day.

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This state of environmental acoustical load shows necessity of making additional efforts in order to improve existing situation. Although there are differences between noise level reduction programs in various countries, joint aspect of work in this field include:

– new residential and industrial zone, highway and airport planning;
– acceptance of complaints and adverse comments made by people, or during the planning process or after that;
– evaluation of the noise level of different noise sources in according to regulations and laws.

In the scope of the cited tasks, it is necessary:

– *on site* noise measurement;
– evaluation of noise produced by specific noise sources;
– calculation of expected noise levels;
– noise level mapping;
– preparing a report on state of acoustical load of the environment, and
– file away and reactivation of collected data.

Existence of different featured noise sources brings into use various methods and indicators for acoustical load state description and evaluation. Therefore, there is a need for changes in approach to the problem, which means adoption of new strategy for accuracy improvement and data standardization in order to improve coherence of different methods and indicators used for description and evaluation of the acoustical load state.

National legislation defines rating noise level use as an indicator for description and evaluation of acoustical load state in the environment. In this paper, there is an algorithmic survey of procedure for rating noise level determination.

2. Selection of noise indicators

The aim of noise indicator selection is to reduce a large volume of information to a quantity which is still meaningful but easier to handle.

Noise indicator selection process contains forming a set of criteria on the base of both scientific validity of indicators and feasibility of indicator application in the practice. The following set of criteria can be formulated:

– **indicator validity** – relationships between indicators and noise effects, first of all speech interference, annoyance and sleep disturbances;
– **practical applicability of indicator** – ease of calculation and measurement using available equipment;
– **indicator transparency** – a small number of simple, easy-to-explain indicators;
– **indicator applicability** - in evaluation of changes or exceeding of the set limit noise level;
– **indicator consistency** - to the ones already in practical use in the most of the countries.

One of the models for selection of indicators is based on breaking down of the possible set of indicators into discrete hierarchic steps [4]. Basic concept of this model, shown on Figure 1, is that sound environment has been observed as a set of a large number of short sound samples with different frequency bands.

Process of information amount reduction contain next steps [4]:
– reduction of frequency contents,
– evaluation of sound event level,
– description of a sound event set within defined time interval,
– description of a sound event set within 24-hour period,
– calculation long-term mean level value.

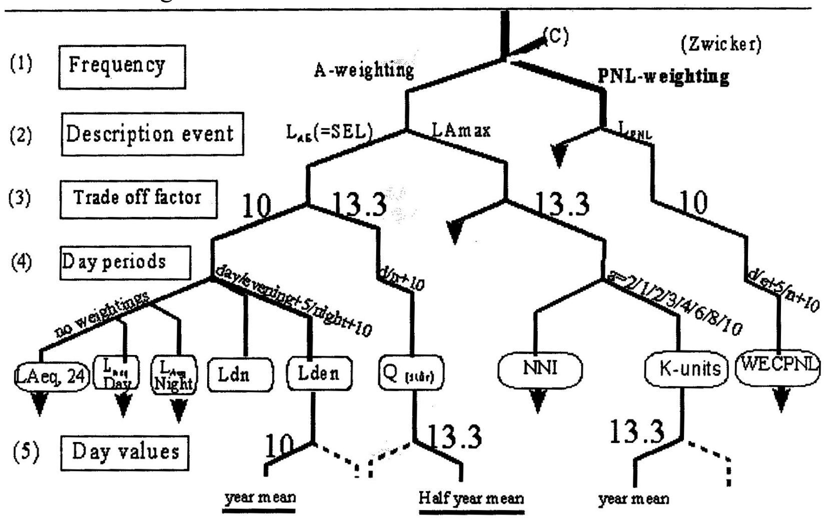


Fig. 1 The model for selection of noise indicators

2.1 Frequency Contents Reduction

Different sensitivity between ear and measuring microphones has caused use of frequency weighting. There are in use A, B, C, D, PNL or Zwicker-Stevens weighting. *A* – weighting is fully accepted for practical use in noise level measurement and evaluation.

PNL (Perceived Noise Level) weighting has any practical application in some airplane noise indicators. However, because of complicated PNL calculating procedure, in many cases this approach has been abandoned and substituted with more simple and wide accepted practice of *A* – weighting which enables PNL level calculation based on *A* – noise level.

Although it is possible to show that other frequency weighting have certain advantages over *A* – weighting, e.g. loudness calculation, it is clear that application of these weighting does not improve correlation between people annoyance and indicators based on this characteristics.

As *A* – weighting level practically tends to underestimate noise below 100 Hz, it is necessary to define a criterion on description noise sources which are to be expected for a low – frequency noise causing disturbances through symptoms as dizziness, vertigo, nausea, etc.

Criteria by which to judge low-frequency noise consists of the difference between C (or unweighted) sound level and *A* – weighted sound level. If the difference exceeds 20 dB, then further analyse of low frequency is necessary in order to obtain more precise results.

2.2 Sound event level evaluation

There are two commonly accepted methods to evaluate the single sound event level. The first method contains use of L_{ea} type indicators where total energy content of event should be taken into account. Resulting value (L_{AE} in accordance with ISO; designated as SEL or L_{AX}) could be used for determination of long-term equivalent noise level as well as for estimation of short-term sleep interference.

The second method takes into account maximum value per event only, thereby ignoring time component of sound event as well as fact that the same equivalent noise level may cause both shorter and longer sound event.

In practical situations, the first approach give more precise sound event description, therefore it is used at the most noise indicators.

2.3 Sound event set description

Set of events in defined time interval can be described in two ways: by the energetic summing of sound events with trade-off factor 10, or by the energetic summing with trade-off factor 13.3.

Although there is a great number of researches involved in definition of the most appropriated trade-off factor, it is not clear enough if trade-off factor, smaller or bigger than 10, can significantly improve sound event correlation with effects. Therefore, trade-off factor 10 is used in the most indicators.

2.4 Description of sound events within a 24-hour period

Since certain human activities are related to certain time period during the day (work – day period, rest – evening and sleeping – night), and sensitivity of a human on environment noise mostly depends on human activity during that period, it is necessary to make partition of day to a few reference time periods, due to more efficient noise protection of population. Definition of these intervals depends on whether conditions and cultural norms that predominate in different time periods of the year in different countries.

Day period should cover mean workday, including the time required for transport to and from the work. Evening period should cover mean time intended for rest and recreation at home, out of normal working day (this may include afternoon rest period). Night period covers mean sleeping time, since going to sleep at the end of a working day till wake-up in the morning. Therefore, it is necessary to conduct research of general behaviour of the population.

After definition of reference time periods and determination of acoustical load level within those periods, next step should be combining of derived values into one which should be competent for 24-hour level. Summing and averaging without value correction have been used for day, evening and night period, as well as summing and averaging the same values with corrections for evening (−5 dB) and night (−10 dB), or for night only (−10 dB).

2.5 Calculation of mean value of the level within a longer time interval

Environmental noise of many sources constantly varies. The variations at the receiving point are consequence of:

a) variations of the source characteristics, and
b) transmission ways variation, which are frequently caused by variations in meteorological conditions.

For the purpose of strategic planning, mapping and zoning of urban areas connected with noise, it is necessary to average noise level over a longer time periods which may comprise day, weekend, summer, winter, a half year, a year, etc.

For relatively constant noise or noise with fixed patterns, as railroad or airplane traffic or large industrial noise sources, there is no practical difference between determination of the equivalent level for shorter or longer period. However, for irregular or intermittent noise, time averaging of noise within longer period is more descriptive than averaging within shorter period.

3. Noise Indicators State

In the most European countries, the same noise indexes are in use: L_r (in accordance with ISO 1996) for industrial noise and L_{Aeq} for road and railway traffic. Exceptions are Belgium for industrial noise (L_{95}), Great Britain for road traffic noise (L_{10}) and Denmark for railway noise (L_{Amax}). In Table 1 are presented noise indicators used in European Community, indicators defined by International Standards (ISO) and indicators defined by national Yugoslav standards [1,5,6]

Rating noise level L_r is calculated on the base of measured A – sound pressure level and correction K_T because of a presence of tonal component and K_I because of an impulsive noise content.

Table 1. Noise indicators for different types of noise sources

	industrial	traffic	
		road	rail
Austria	L_r	L_{Aeq}	$L_{r=} L_{Aeq} - 5$ dB
Belgium	L_{95}		
Denmark	L_r	$L_{Aeq,24h}$	$L_{Aeq,24h}$, L_{Amax}
France	L_r	L_{Aeq}	$L_{Aeq,12h}$
Germany	L_r	$L_{r=} L_{Aeq} + K$	$L_{r=} L_{Aeq} - 5$ dB
UK	L_r	L_{Aeq}, L_{10}	L_{Aeq}
Italy	L_r	L_{Aeq}	
Netherlands	L_r	L_{Aeq}	L_{Aeq}
Spain	L_r	L_{Aeq}	
Sweden	L_r	$L_{Aeq,24h}$	$L_{Aeq,24h}$
ISO	L_r	L_{Aeq}	L_{Aeq}
Yugoslavia	L_r	L_{Aeq}	L_{Aeq}

Although the same noise indicators are in use in the most of the countries, there are significant differences in the way of:

– correction definition K_T and K_I;
– reference time intervals;

– meteorological conditions counting in;
– determination of measuring positions (facade or free field);
– averaging within a longer time period.

Corrections for tonal components are ranging from 2 to 6 dB (Table 2). In some countries there is in use one value (5 dB), which corresponds to recommendation of ISO 1996 – 1971, while the other use two values, which corresponds to ISO 1996 – 1987 [7]. Correction determination is mainly based on the subjective evaluation of the tonal components presence.

Table 2 Tonal and impulse corrections in different countries

	K_T	K_I
Austria	3; 6	3; $L_{AI\max} - L_{AF\max} < 2dB$ 5; $L_{AI\max} - L_{AF\max} \geq 2dB$
Belgium	2÷6	5; $L_{AI\max} - L_{AS\max} > 5dB$
Denmark	5	5
France	5	3; 5; 10
Germany	3; 6	$L_{AI\mathrm{eq}} - L_{A\mathrm{eq}}$; $L_{AFT\mathrm{eq}} - L_{A\mathrm{eq}}$
UK	5	5
Italy	3	3; $L_{AI\max} - L_{AF\max} > 6dB$
Netherlands	5	5
ISO	2-3; 5-6	–
Yugoslavia	3; 6	3; $L_{AI\max} - L_{AF\max} < 2dB$ 5; $L_{AI\max} - L_{AF\max} \geq 2dB$

There are different procedures and values for impulsive correction (Table 2). There are subjective and objective methods for impulse correction determination and values are ranging from 3 to 10 dB. ISO standards define no impulse correction.

There are some differences in reference time periods and time intervals in which noise evaluation are done (Table 3). Whole 24-hour period is in use, some countries use day division into two referent time intervals: day and night, while the others introduce third period of rest in order to achieve more efficient protection of population during this period.

Regarding the state of noise indicators in European countries, the proposal was formulated for harmonization of physical noise indicators in countries of European Community, for noise description of all kinds of external noise sources [6].

Key recommendations are:

– For the assessment overall noise impact, noise levels in day, evening and night period should be combined into one level L_{EU}, with weighting of +5 dB for the evening and 10 dB at night:

$$L_{EU} = 10\log\frac{1}{24}(12\cdot 10^{0.1L_d} + 4\cdot 10^{0.1(L_e+5)} + 8\cdot 10^{0.1(L_n+10)}) \tag{1}$$

where L_d, L_e and L_n equivalent noise levels for day, evening and night period, respectively.

Table 3. Reference time intervals

	day	rest	night
Austria	(6–22)8h	–	(22–6)0.5h
Belgium	1h	1h	1h
Denmark	(7–18)8h	(18–22)1h	(22–7)0.5h
France	(7–20)o.t.	(6–7;20–22)o.t.	(22–6)o.t
Germany	(6–22)16h	–	(22–6)0.1h
UK	(7–23)	–	(23–7)
Italy	(6–22)16h	–	(22–6)8h
Netherlands	(7–19)12h	(19–23)4h	(23–7)8h
Sweden	(7–18)	(18–22)	(22–7)
ISO	–	–	–
Yugoslavia	(6–22)		(22–6)

For night period sleep annoyance assessment, $L_{EU,N}$ level should be used as an equivalent level for an eight hour night period.

It is necessary to define previous two indicators for every single noise source.

– Time period length;

The suggestion is given that day, evening and night period should be12 hours (07:00-19:00), 4 hours (19:00-23:00) and 8 hours (23:00-07:00), respectively. It is possible that some countries define the limit values of time periods themselves, regarding their unique features (geographic position, habits, etc.), but European Community should be informed about it.

– Measurement of incidental noise level minimizing facade reflection effect;

– Measurement height;

Noise indicators are determined for incident noise level at height of 4 meters above the ground. This height gives better description of noise exposure of the second floor rooms in small two floor houses. Also, it minimizes the ground reflection directly underneath the microphone.

– Measuring of incidental levels for most exposed facades;

In case of apartments being exposed to different noise sources on the same or different facades, and if it is necessary to define overall value of indicator, then determination of noise indicators for the most exposure facades is recommended.

– Noise indicators for separated noise sources and time periods should be representative for a calendar year, and for a season of the year, if necessary; additional values for weekend are recommended, as well.

4. Rating noise level determination procedure

National legislation that include these standards:

– JUS U.J6.090 (Community noise measurement) [8],

– JUS ISO 1996 (Description and measurement of environmental noise) [9],

– JUS U.J6.205 (Acoustical zoning) [10],

– Regulations for permissible noise level in the environment [11], and

– Environment noise measurement methods [12],

define the environmental noise measurement and evaluation methods. For description and evaluation of environmental noise, the rating noise level is used as an equivalent *A* – noise level that refers to defined referent time, with correction for noise character.

Rating noise level determination procedure is algorithmically shown on Figure 2.

The base of this procedure is measurement of *A* - equivalent noise level by application of three recommended methods: integration procedure, sampling method and sorting method. Measurement of *A* – equivalent noise level is in application for all types of noise sources, except for source of intermittent noise character. Equivalent noise level is determined by measuring incidental noise level at height of 1,2 to 2.0 meter above the ground. For exceptional measurement tasks (wall screen, ground slope, large ground dumping) the measurement can be done on the height of 4 meters.

For the source with intermittent character of noise, *A* – equivalent noise level, L_{Aeq}, is determined by sound exposure level, L_{AEi}, for every noise source which appears during measure interval, *T*:

$$L_{Aeq} = 10\log\frac{1}{T}\sum_{i=1}^{n}10^{0.1L_{AEi}} \tag{2}$$

After determination of *A* – equivalent noise level, it should be established if the noise of observed sources contains impulses, emphasized tones or some different acoustical data, in order to determine measured level correction.

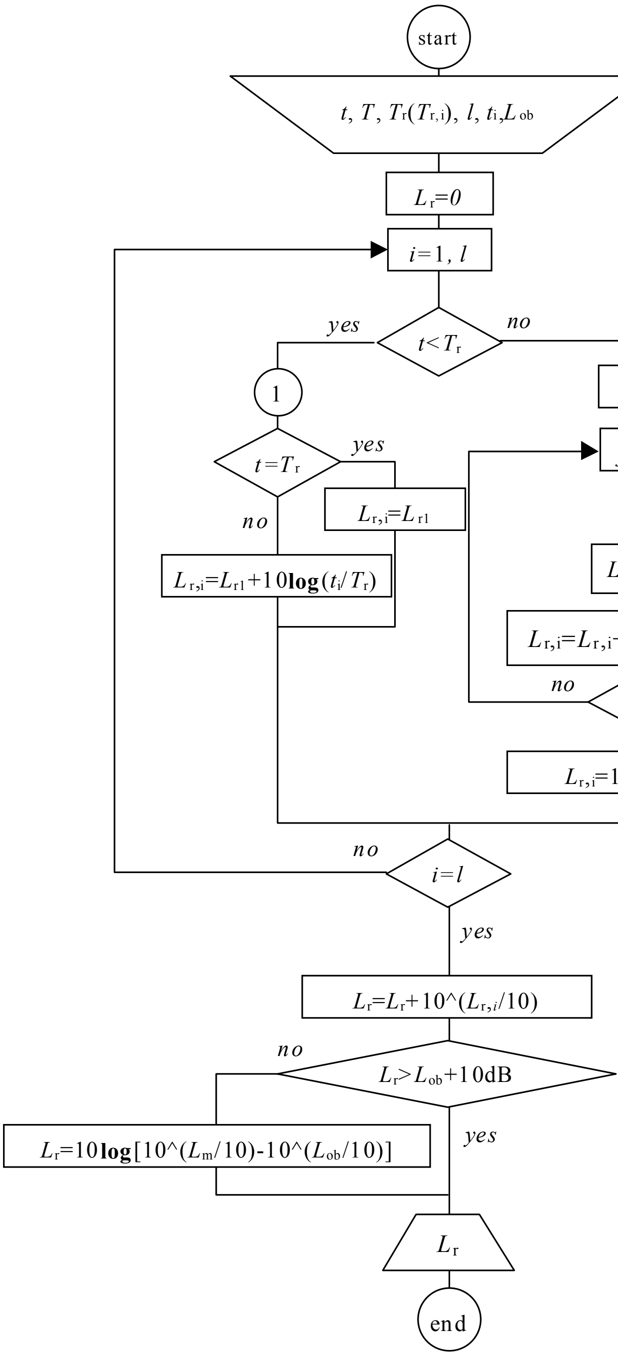
If noise contain impulses, than it is necessary to determine time, frequency and impulse time arrangement. For determination of correction for impulse content of noise, it is necessary to determine maximum *A* – noise level with "impulse" time constant, $L_{A\max,I}$, and maximum *A* – level with "fast" time constant, $L_{A\max,F}$. Impulsive content correction, K_I is:

$$K_I = \begin{cases} 5\text{dB ako je } |L_{Amax,I} - L_{Amax,F}| \geq 2\text{dB} \\ 3\text{dB ako je } |L_{Amax,I} - L_{Amax,F}| < 2\text{dB} \end{cases} \tag{3}$$

For determination of tonal character of noise it is necessary, by use of frequency analyses, to determine 1/3 octave noise spectrum. If the tonal component is clearly audible and if 1/3 octave spectrum shows 1/3 octave bands which overrun adjacent bands for 5 dB or more, then tonal character correction is $K_T = 6$ dB. If the tone is clearly audible, but it is impossible to proof its existence by 1/3 octave analysis, then the correction is $K_T = 3$ dB.

If observed source noise contains other acoustical information (mostly music), then it is necessary to determine the time of appearance, kind and level of noticeability. If the phenomenon is extremely noticeable, acoustical information presence correction is $K_M = 5$dB.

For rating noise level determination, besides observed noise character, the rate of duration of evaluated noise and reference interval that has been used for noise evaluation is very important. Since Yugoslav regulations do not explicitly define duration of reference interval, starting from the practices applied in the most of the countries, authors of this paper have accepted division of a day into two referent periods. That division has been defined by Yugoslav regulations, so for measurements in day conditions the referent interval is 16 hours (6:00-22:00), and for night measurements 8 hours (22:00-06:00).


start
t, T, Tr(Tr,i), l, ti,Lob
Lr=0
i=1, l
t<Tr
yes
no
1
Lr,i=0
t=Tr
yes
j=1, n
Lr,i=Lr1
no
1
Lr,i=Lr1+10log(ti/Tr)
Lr,Trj=Lr1
Lr,i=Lr,i+10^(Lr,Trj/10)
no
j=n
yes
Lr,i=10log(Lr,i/n)
no
i=l
yes
Lr=Lr+10^(Lr,i/10)
no
Lr>Lob+10dB
yes
Lr=10log[10^(Lm/10)-10^(Lob/10)]
Lr
end

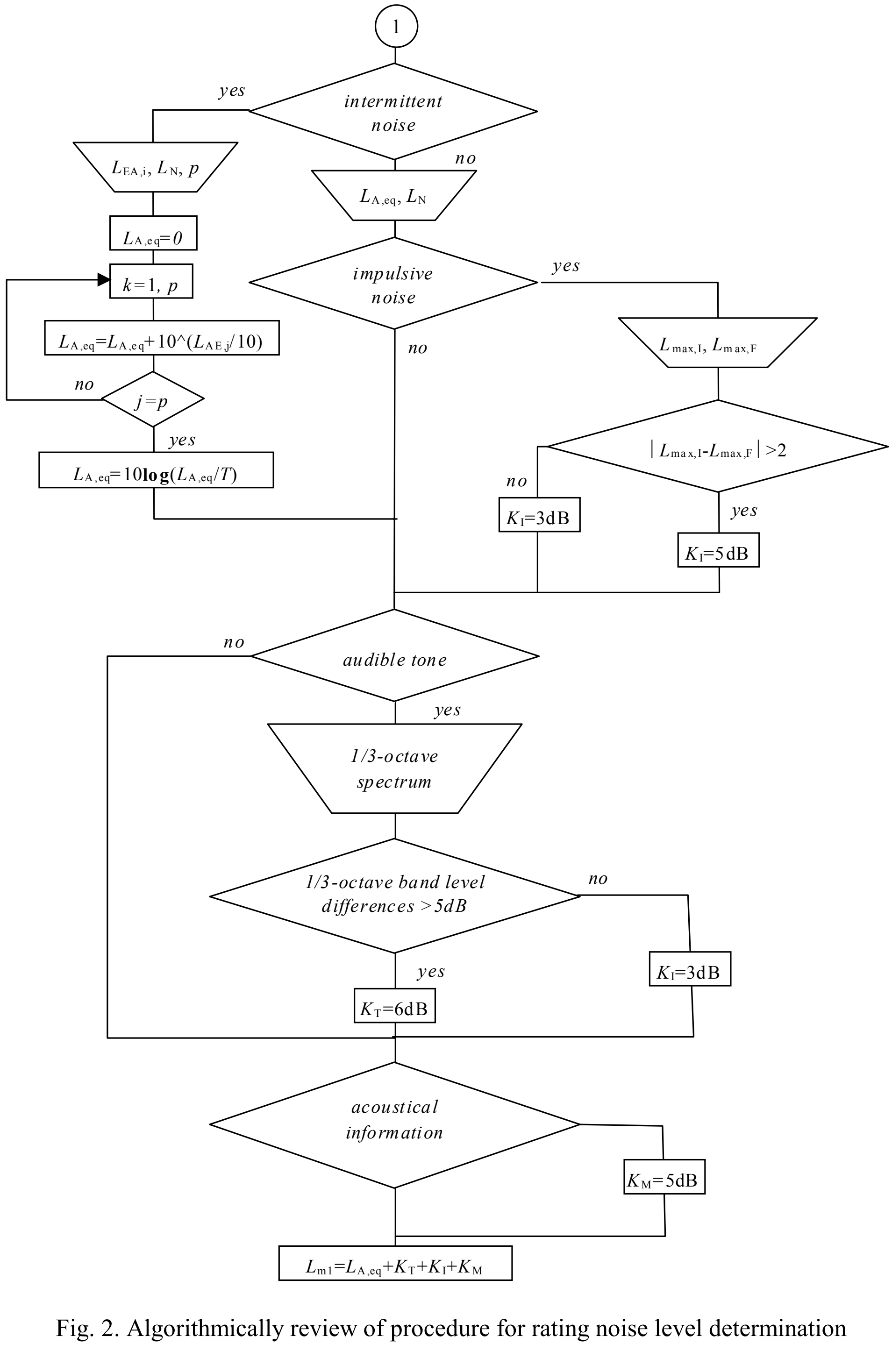


Fig. 2. Algorithmically review of procedure for rating noise level determination

If duration of evaluated noise is shorter than reference interval, then noise level is scaled to reference interval trough this expression:

$$K_t = 10\log\frac{t}{T_r} \tag{4}$$

If the noise duration comprises more reference intervals, it is necessary to determine equivalent *A*-level for each interval, and then perform energetic summarization of derived results with night period correction $K_R = -10$ dB.

After determination of all mentioned corrections, it is possible to determine rated noise level as:

$$L_m = L_{Aeq} + K_I + K_T + K_M + K_t + K_R \tag{5}$$

When evaluated noise is generated by sources of different characteristics and different duration, then should determine rating noise level for each source individually, scaled to the same reference level, and then those intervals should be energetically summarized in order to derive total rated level:

$$L_m = 10\log\sum_{i=1}^{n} 10^{0.1L_{mi}} \tag{6}$$

If evaluated noise can not be determined due to the presence of background noise which level differs from evaluated noise for less than 10dB, then rating level of evaluated noise is to be determined as energetic difference of rating total noise level (including observed noise and background noise) and rating background noise level:

$$L_m = 10\log(10^{0.1L_{m,ub}} - 10^{0.1L_{m,pb}}) \tag{7}$$

5. Conclusion

Existence of different methods and indicators for description and evaluation of state of acoustical load in environment create a need for changes in entire approach to this problem, which should contain adoption of new strategy for accuracy increase and data standardization in order to improve coherence of different methods and indicators for acoustical load description and evaluation.

Therefore, it is necessary to harmonize Yugoslav regulations covering field of measurement, description and evaluation of acoustical load of human closest environment by means of:

- day division adoption on three time periods in order to achieve more efficient population protection: day (6:00-18:00), evening (18:00-22:00) and night (22:00-6:00),
- definition of reference intervals in accordance with adopted day division (12 hours for day period, 4 hours for evening period and 8 hours for night period),
- adoption of weighting noise level in different time intervals (0 dB for day period, -5dB for evening period and –10 dB for night period) in order to determinate rating long term noise level.

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12. *Environment noise measurement methods*

MERODAVNI NIVO BUKE - INDIKATOR BUKE U ŽIVOTNOJ SREDINI

Dragan Cvetković, Momir Praščević

U strukturi formiranog akustičkog opterećenja životne sredine dominiraju izvori buke različitih karakteristika, što dovodi do upotrebe različitih indikatora za opis i ocenu stanja akustičkog opterećenja. Izbor odgovarajućeg indikatora buke između različitih alternativa ima za cilj redukovanje velike količine informacija na mali broj indikatora koji su jednostavni za korišćenje, ali još uvek sadrže značajnu količinu informacija. Nacionalnim zakonodavstvom u ovoj oblasti definisane su metode merenja i ocene nivoa buke u životnoj sredini korišćenjem merodavnog nivoa buke. Polazeći od korišćenih metoda u različitim evropskim zemljama, metoda definisanim nacionalnim propisima i dugogodišnjeg iskustva u merenju buke u životnoj sredini, autori ovog rada daju algoritamski prikaz procedure za određivanje merodavnog nivoa buke različitih karakteristika.

Ključne reči: *merodavni nivo buke, indikator buke, ocena buke*