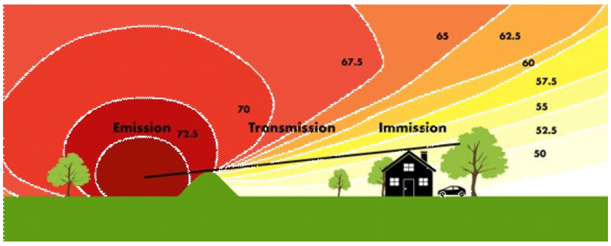
NoizCalc
Technical white paper (1.2 en)

Contents

1. Introduction

This Technical white paper describes NoizCalc, a software program to calculate the noise immission from sound systems defined in the ArrayCalc simulation software including meteorological influences and a 3D terrain model.

1.1 Transmission, emission to immission



The prediction and control of noise immission from live events has become a more and more serious topic, particularly as the events increase in size and promoters wish to place a number of these within densely populated urban areas. Gaining permission and licences to stage an open air event frequently requires an official statement with a prediction of how noise could impact the surrounding area. A prediction of the effect of diurnal temperature variations plotted over a time histogram corresponding to the time of day when the event takes place could be among the requested data. This type of requirement already exists in many parts of the world. It is not a new topic for people on both sides of the situation: those in measurement and enforcement (immission experts), and the performers, promoters, technicians, loudspeaker suppliers (emission experts) and audience.

Since both the placement of a stage and the loudspeaker system design can influence where sound is emitted outside the audience area, their impact on potential noise immission is a significant consideration, both during the planning stages and throughout an event. The d&b objective is to put tools in place to give a greater understanding of the way complex high directivity sound systems interact with the wider area surrounding an event.

From experience, it is clear that careful planning of the combined directivity achieved by a sound system and the direction in which this points can influence the result.

1.2 The problem

The sound system design software specifically targets the audience with the objective of achieving an even frequency response and tailored level distribution over the whole listener area. All complex addition and subtraction of sound waves from a complete system setup is taken into account. d&b ArrayCalc creates a prediction of the direct sound from the system, it does not model the reflections from any surfaces that might be present. The effects of reflections, mitigation and weather are necessary to calculate the performance of a high directivity loudspeaker system over larger distances into the areas outside of the audience.

Conversely, the prediction tools available to study sound propagation over distance use noise sources with completely different characteristics to a typical line array sound system with its associated subwoofers and fills. These tools are designed to analyse the impact of noise from roads, railways, industrial plants or various types of public events, which is quite different to the impact of a finely adjusted coherently radiating multi element loudspeaker system.
To achieve an accurate prediction of sound propagation over longer distances it is critical that all aspects of a loudspeaker system are correctly introduced into the model. This must include all the complex data including phase information, describing the combination and interaction effects within a loudspeaker system consisting of multiple line arrays, subwoofer arrays and delay systems.

1.3 The solution

The d&b ArrayCalc simulation software is widely recognized as a very accurate tool for its purpose. The software allows complex loudspeaker systems to be modelled, consisting of many types of d&b loudspeaker, including line arrays, point sources, subwoofer arrays, fill and delay systems. It allows a system designer to make adjustments to the way the elements of systems are placed and powered to achieve the desired result.

The acknowledged German specialist SoundPLAN is one of the leading software developers in the field of environmental noise prediction. The complete integration of indoor factory noise, transmission through walls and the noise propagation into the environment make this software the ideal tool for engineers working in the fields of noise planning, noise in the workplace, 3D terrain noise mapping and as part of general environmental assessment studies. The unsurpassed numerical and graphical presentations make it easy to explain the findings to the public and to agencies requesting studies. The SoundPLANnoise software implements all common worldwide noise prediction standards (around 40 different standards), these include ISO 9613-2 and Nord2000.

1.4 The products

Two products are available, one from each of the cooperating companies: d&b NoizCalc, a new software program to model the far field performance of d&b sound systems in the open air, while the SoundPLANnoise software is capable of importing all the setup information of a complete d&b loudspeaker system.

To achieve this the NoizCalc and SoundPLANnoise software tools both import d&b ArrayCalc project files, which include all the complex data describing relationship between sources and the performance of complete d&b system setups. Both programs allow loudspeaker setups to be placed and oriented within 3D terrain models to enable prediction of the far field performance over the area surrounding the proposed installation. In the event planning stages, the impact of the potential system can be appraised, allowing careful consideration of the components, their aiming and potential immission issues of the proposal. In the quest for a best case scenario, experiments with changes to the system setup can be made in ArrayCalc then directly imported into NoizCalc or SoundPLANnoise.

1.5 Why two products?

Both software packages use 3D digital terrain models and are based on the SoundPLAN calculation engine. NoizCalc is intended for use by sound system designers to investigate how their loudspeaker systems will impact on a wider area, typically the area well outside of the audience at an open air event. SoundPLANnoise also offers this functionality while additionally offering comprehensive reporting tools to satisfy the need for an official noise immission statement when a licensing authority makes this a requirement.

2. NoizCalc

NoizCalc is meant to predict the propagation of sound from an outdoor event in the far field. Calculated is the momentary SPL distribution in dB(A) with a chosen signal spectrum and a chosen SPL level at the reference point (usually Front of House). Two propagation models are available for calculations: ISO 9613-2 and Nord2000.

2.1 What NoizCalc does

!Note: NoizCalc calculates the propagation of sound from the source (a stage or multiple stages) to the grid points on the calculation area. The calculation is done according to the chosen propagation model and takes the directivity and interaction of complex loudspeaker setups along with several propagation effects into account. The noise map resulting from the calculation should be seen as the momentary value with the given sound system setup, signal spectrum, terrain and meteorology.

2.2 What NoizCalc doesn't do

NoizCalc doesn't offer any evaluation of the calculation results in terms of a time histogram or any indication if the allowed noise levels in the neighbourhood are exceeded. In order to obtain this kind of prediction, one should include an acoustic consultant.

2.3 The workflow

The planning process starts as usual: a loudspeaker system is designed in an ArrayCalc project. When the first design is ready, the NoizCalc project has to be setup.
In NoizCalc, the first step is to select the propagation model.

> **Note:** It's important to select the propagation standard at the very beginning, because the object properties depend on it. In order to compare calculations according to ISO 9613-2 and Nord2000, two projects must be set up. Setting up one project and then simply changing the propagation model would not work, because all the object parameters would be set to default.

Then the project is initialized via the ArrayCalc project.
The next step is to create the Digital Ground Model (DGM). The easiest way is to use elevation data from Google, which can be imported into NoizCalc. By zooming into the location of the event the calculation area is chosen.
After the terrain is imported, the stage or stages can be placed. A separate ArrayCalc project can be assigned to each stage.
All the relevant data is read from the ArrayCalc project: the layout and directivity of the loudspeakers, the filter settings and the snapshot of the system. All relevant loudspeakers should be unmuted and the active AP slot should be selected when ArrayProcessing is in use.
Now the spectrum and the reference level of every stage has to be defined.
After the stage is set up, all the relevant objects to the noise propagation are specified on the DGM. By default, all "ground" is assumed porous and absorbing, so all hard ground must be entered.
Forests can be included. In ISO 9613-2 only the height of the trees is a parameter, whereas Nord2000 offers the choice of other parameters like the mean tree density and the stem radius.
"Buildings" reflect the noise and create shadow effects that will influence the results especially in urban areas, so they should be taken into account.
"Walls" can be used to model actual walls or standalone tribunes, for example, a race track.
When modelling buildings, it is important to define the gaps between the buildings correctly, especially when close to the source and the main points of interest on the calculation area. The shielding by buildings has a significant effect, so the more precise modelling, the better the prediction.
When the model is ready, the grid noise map is calculated, and the result appears in the Graphic plot tab. If the result is not satisfying, either the location and direction of the stage can be adjusted, or the sound system parameters can be modified. For the latter, ArrayCalc can be opened directly from NoizCalc. The process can be repeated until the desired result is achieved.

3. How does it work?

NoizCalc models the complex summation of the emission from all the sources including propagation effects at every grid point. Basically, NoizCalc repeats the ArrayCalc complex summation, but including the "adventures" of the sound from each source on its propagation track.

Predicting outdoor sound is a very challenging task. There are porous and not so porous grounds that are unknown, atmospheric effects, layers of air at different temperatures, different wind speeds, turbulence, forests, buildings and multiple reflections between them. Each of these effects could be modelled precisely, as long as the relevant parameters are known, such as the exact porosity of the ground or the temperature or wind speed profile. In reality, this data is seldom available, and moreover, all the combined effects are almost impossible to model precisely.

3.1 Following the standards

However, predictions must be made and compared. The only way to deal with that is to introduce propagation models or standards – the guidelines for environmental noise calculations that everybody has to follow.
A variety of propagation models has been developed. Some of them were developed mainly for industrial noise, some for road and rail noise, some are source-independent.

3.2 The choice of the propagation model

The choice of the propagation model depends either on the local authorities who can specify the required calculation standard, or on the purpose of the calculation.

If only the worst case scenario calculation is needed, and almost no meteorological information is available, or the calculation must be completed quickly, then ISO 9613-2 is appropriate.

Nord2000 is a more sophisticated propagation model that requires more meteorological information and longer calculation times, but offers calculations of different scenarios depending on the weather conditions, with a more precise handling of various effects.

The challenge of the environmental noise prediction is to represent reality in the most precise way, staying within the guidelines.

4. Propagation models

A few things can happen to sound on it's journey from source to receiver. It's radiated, directed, diverged, absorbed into the atmosphere, reflected and absorbed by ground, and has to travel over barriers along with a number of other effects.

All these effects are treated separately and independently, and also differently in ISO 9613-2 and Nord2000.

> **Note:** ISO 9613-2 originally intended calculations with a representative frequency or in octave frequency bands. Nord2000 prescribes calculations in third octave bands. In NoizCalc the calculation can be done optionally with single values, octave or third octave bands. The results are shown as the sum level with either A- or C-weighting.

Both models use the same approach to the calculation: the sound pressure level at the receiver is calculated as the sum of the sound power of sources including the directivity factor and minus the sum of all attenuation factors in dB.

$$L = L_W + D_c - A$$

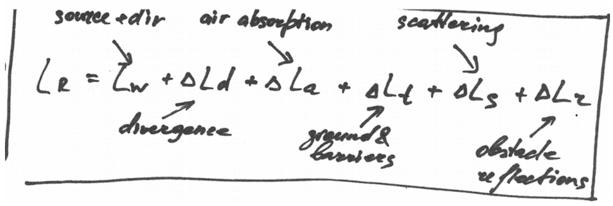
The attenuation factors are:

- geometrical divergence (the "far field" -6dB per doubling of the distance)
- atmospheric absorption
- ground effect
- attenuation due to barriers
- additional types of attenuation (forest etc.)

$$A = A_{div} + A_{atm} + A_{gr} + A_{bar} + A_{misc}$$

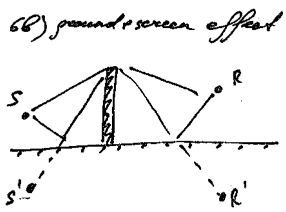
In Nord2000 the effects are combined a little differently, but the calculation follows by the same principle: the sound pressure level at the receiver is a sum of the level of the source, including directivity, plus the effects of air absorption, ground and barriers, scattering, obstacles and reflections.

The overviews of both standards are given in the Appendix.



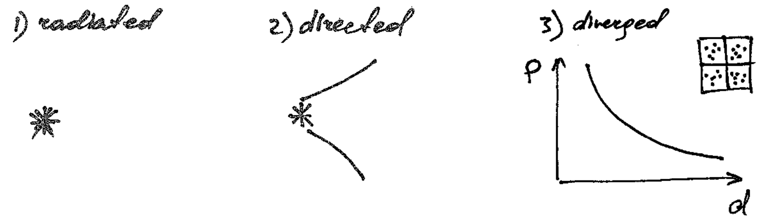
The overviews of both standards are given in Appendix.

The following table briefly describes how the effects are treated in both standards. Precise information can be found in [1] and [2].

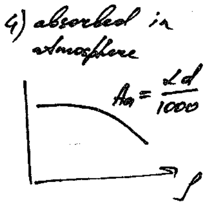


ISO 9613-2	Nord2000

Propagation



Atmospheric absorption

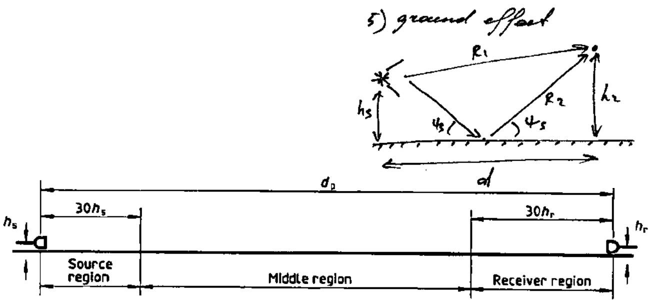


Tempera-ture	Relative humidity	Atmospheric attenuation coefficient α, dB/km							
		Nominal midband frequency, Hz							
°C	%	63	125	250	500	1 000	2 000	4 000	8 000
10	70	0,1	0,4	1,0	1,9	3,7	9,7	32,8	117
20	70	0,1	0,3	1,1	2,8	5,0	9,0	22,9	76,6
30	70	0,1	0,3	1,0	3,1	7,4	12,7	23,1	59,3
15	20	0,3	0,6	1,2	2,7	8,2	28,2	88,8	202
15	50	0,1	0,5	1,2	2,2	4,2	10,8	36,2	129
15	80	0,1	0,3	1,1	2,4	4,1	8,3	23,7	82,8

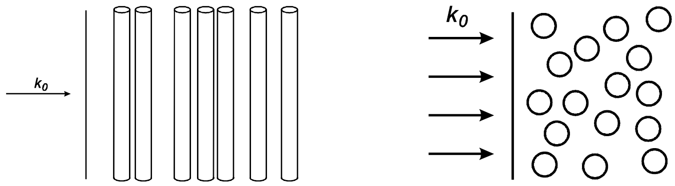
Atmospheric absorption is handled according to ISO 9613-1 in both standards. In ISO 9613-2 only midband frequencies are calculated, in Nord2000 the values are extrapolated into the frequency bands.

Ground effect

ISO 9613-2: Based on empirical constants

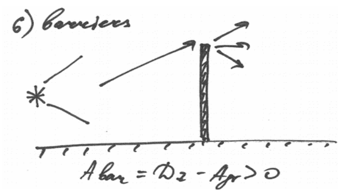


Nord2000: Based on flow resistivity



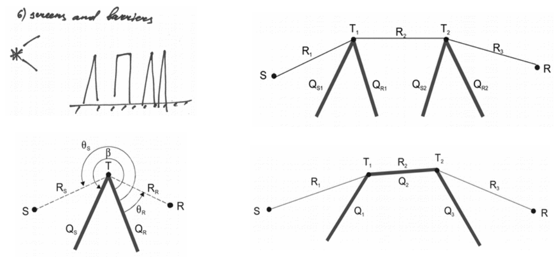
Screens and barriers

ISO 9613-2:

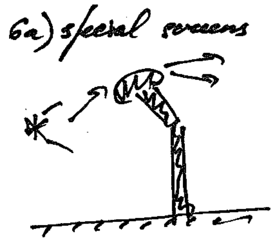


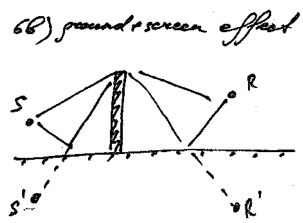
One type of barriers, calculation based on empirical values

Nord2000:



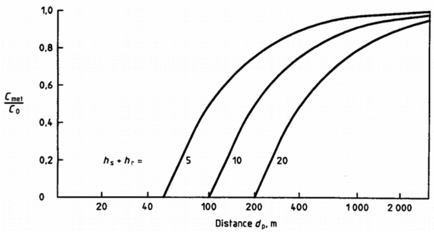
Multiple types of barriers

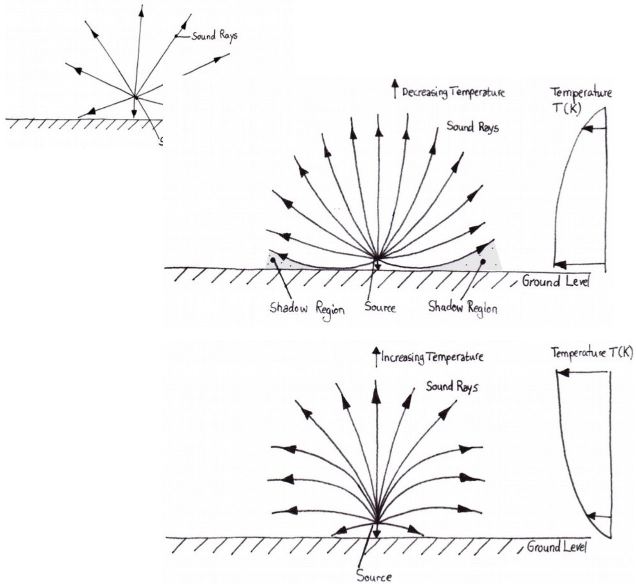
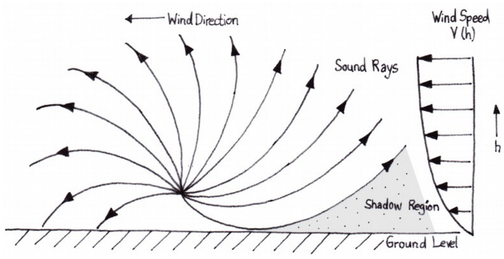




Possible to introduce measured data for special types of barriers

ground and screen effects are considered in combination

<table>
<tr><th>ISO 9613-2</th><th>Nord2000</th></tr>
<tr><td colspan="2">Meteorological effects</td></tr>
<tr><td>One meteorological constant, averaged over a long time


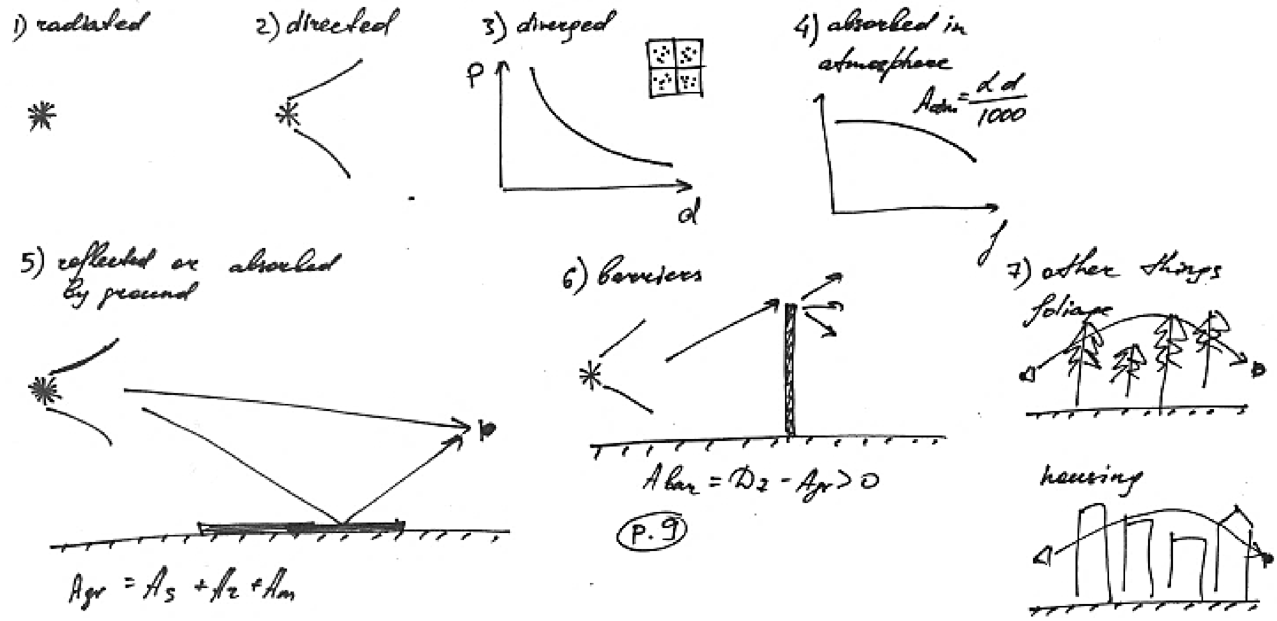
$C_{met} = C_0 \left[1 - 10(h_s + h_r)/d_p\right]$
$d_p > 10(h_s + h_r)$
$L_{AT}(LT) = L_{AT}(DW) - C_{met}$</td>
<td>Allows calculations according to different weather conditions, including temperature gradients, wind speed and direction.

</td></tr>
<tr><td></td><td>
</td></tr>
<tr><td>Worst-case scenario: downwind from the source of sound</td><td>Both worst-case and actual weather scenarios are possible</td></tr>
</table>

5. Appendix

ISO 9613-2

$$L = L_W + D_c - A$$

$$A = A_{div} + A_{atm} + A_{gr} + A_{bar} + A_{misc}$$



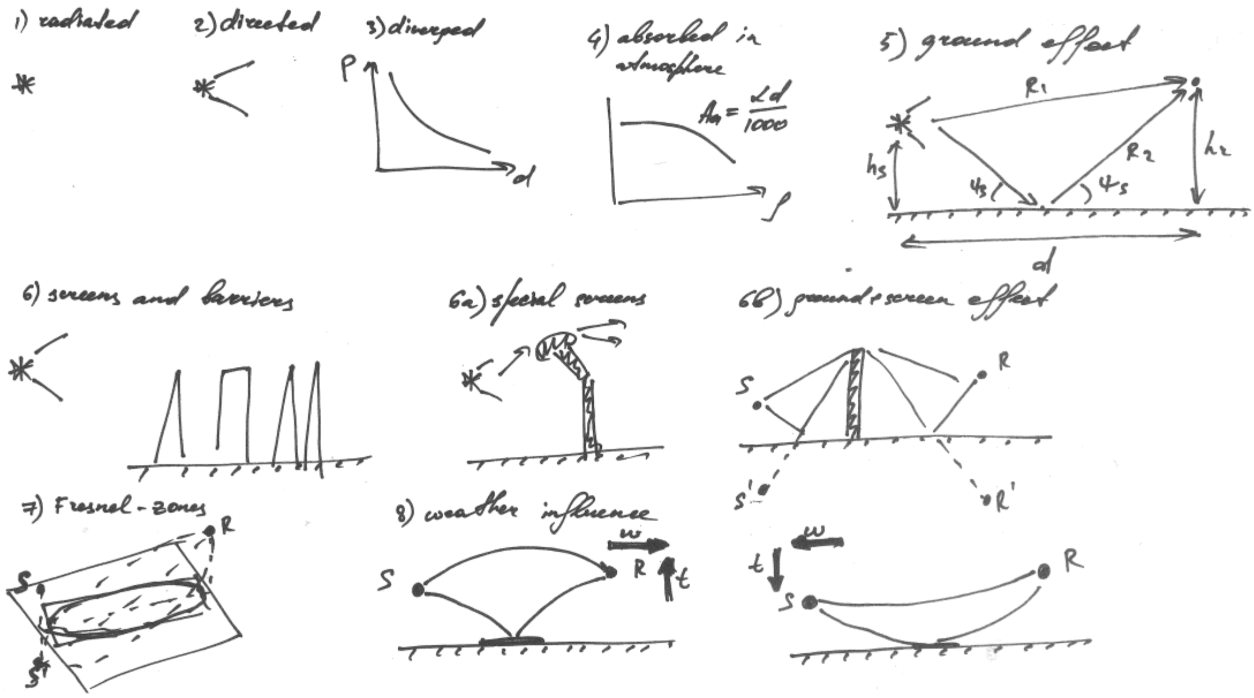
Nord 2000

p.24

$$L_R = L_W + \Delta L_d + \Delta L_a + \Delta L_t + \Delta L_s + \Delta L_r$$

(source + dir; divergence; air absorption; ground & barriers; scattering; obstacle reflections)

(within a frequency band)



6. Simulation limits

The calculations are only as good as the models and the standards.
ISO 9613-2 is considered to be accurate in the distance range up to 1 km. Nord2000 provides high accuracy up to 1 km and good accuracy up to 3 km, however, the model was validated at the distance of 200m.
Precise input data increases the quality of the simulation, so the user has a great influence on the quality of the results. However, the model is based on the specific parameters used during the calculation, so if changes to the meteorological conditions such as wind speed or direction occur, the results may not be reliable.

7. References

1. ISO 9613-2
2. Delta, Nordic environmental noise prediction method, Nord2000, Summary Report
3. Delta, Nord2000. Comprehensive outdoor sound propagation model. Part 1: Propagation in an atmosphere without significant refraction
4. K. Attenborough, K.M. Li, K. Khoroshenkov, Predicting outdoor sound

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