SOPRANOISE: EU Research on new techniques to characterize Noise Barriers acoustic performances

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ABSTRACT

SOPRANOISE (Securing and Optimizing the Performance of Road traffic noise barriers with New methOds and In- Situ Evaluation) is a new European research targeting the in-situ intrinsic acoustic performances of noise barriers, whatever those barriers are placed along roads or along railway tracks.

Even if the European (CEN) standards EN1793-5 and EN1793-6 have been initially drafted for certification of product to be used under direct sound field conditions, they also shown their ability to measure, to some extent, the in-situ intrinsic sound absorption / reflection and airborne sound insulation of noise barriers. However, there is still interest / need to simplify their use alongside roads and railway tracks. SOPRANOISE will update the State Of the Art about today in-situ methods, their significance and their accuracy to characterize the noise barriers intrinsic acoustic performances, as well as their ability to be used in a quick and safe

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manner. Investigations will start from the easiest in-situ inspection methods up to future improved versions of the existing EN1793-5 and EN1793-6.

In- between, there is a gap for simplified and safe methods: SOPRANOISE aims to define the right methods for the right levels of decision, from the simplest to the most accurate characterization.

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1. INTRODUCTION

The overall acoustic performance of noise barriers to reduce road noise towards the environment is a complex process that includes not only the noise barriers implementation and their geometrical dimensions, but also their "intrinsic quality" (i.e.: the acoustic quality directly pertaining to the products themselves). To verify if installed noise barriers are effectively respecting the tender requirements on intrinsic acoustic performances, one has to test those in a fair way: as they are installed (involving the quality of the products and how they are installed).

EN1793-5 [1] and EN1793-6 [2] are the relevant European standards for characterizing the intrinsic sound absorption / reflection and airborne sound insulation performances of noise barriers under those effective (direct sound) field conditions: their measurement methods can be used in different places, e.g.: in laboratories, at manufacturer plants or alongside roads [3] and railways, as soon as the direct sound field conditions are respected. However, they require quite lengthy tests that could also be affected by practical conditions (weather conditions, safety, accessibility…), as well as the need of expert users: this can limit their use alongside roads. While always keeping the possibility to use EN1793-5 and EN1793-6 on site, there is a need for new "quick methods" that could be easier, faster and safer.

In addition to quantitative methods, some road authorities today undertake much simpler but cost effective visual and aural in-situ inspections in order to verify the integrity of the different parts of installed noise barriers [4]. Those inspections are the easiest tools to investigate installed noise barriers: implementing in-situ inspections in a systematic, validated and official scheme could be very useful.

The target of SOPRANOISE is to reply to those needs. Initially scheduled from 2019-12 until 2021-11, this had to be reviewed due to the COVID-19: at this early stage of the research, finalized results are less than expected. The present paper will then mainly focus on the research structure and its target with the preliminary methodologies considered to achieve its objectives.

2. SOPRANOISE OBJECTIVES

SOPRANOISE focus on the following topics:

- State of the Art of the acoustic performances of existing noise barriers.
- Effect of the acoustic degradations of noise barriers.
- In-situ inspection tools.
- Quick and safe methods to be used alongside roads.
- Practical Guidelines on noise barriers

Those topics have been distributed in four Work Packages (WP) that are presented in the next section

3. SOPRANOISE STRUCTURE

Figure 1, presents the whole research structure.

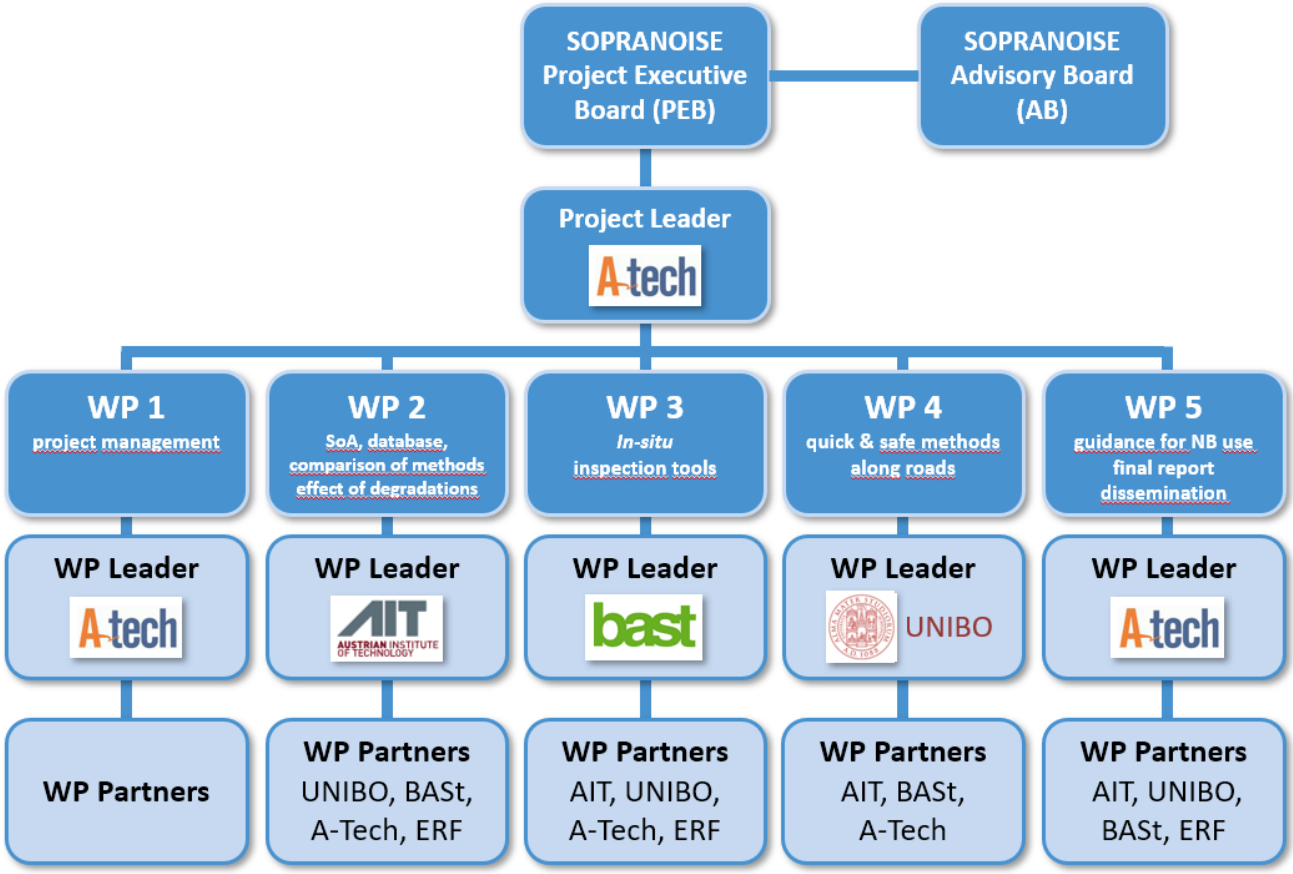

Figure 1: SOPRANOISE whole project structure [©SOPRANOISE]

The SOPRANOISE team comprises the following main partners: A-Tech, AIT, UNIBO, BASt and ERF: each work package has a WP leader and also involves all the other partners. CEDR closely follows and helps the research as representing the relevant road authorities, while ERF (European Road Federations) represents the noise barriers market stakeholders (manufacturers and installers).

WP1 being the "project management" package is not detailed here, while the scientific parts corresponding to WP2, WP3, WP4 and WP5 described here after.

4. WORKPACKAGE 2: SOA, DATABASE, EFFECT OF DEGRADATIONS

WP 2 has three objectives.

The first one is to establish the State of the Art regarding the physical significance, correlations (if any) and possible trends between the diffuse sound field methods (EN1793-1 [5] and EN1793-2 [6]) and the corresponding direct sound field methods EN1793-5 [1] and EN1793-6 [2] that are the relevant ones to characterize (free-standing) noise barriers: the results of this SoA are just reported and will be available for the presentation.

The second objective is the update and extension of the relevant database of the noise barriers products on the EU market, including not only (certified) manufactured products, but also already installed noise barriers. This new database will emphasize facts and figures about acoustic performances obtained from both the diffuse and direct sound field methods. Figure 2 presents the entity-relationship of the newly built database: at the date of drafting this paper, more than 110 additional dataset have been collected and merged with the existing QUIESST [7] database.

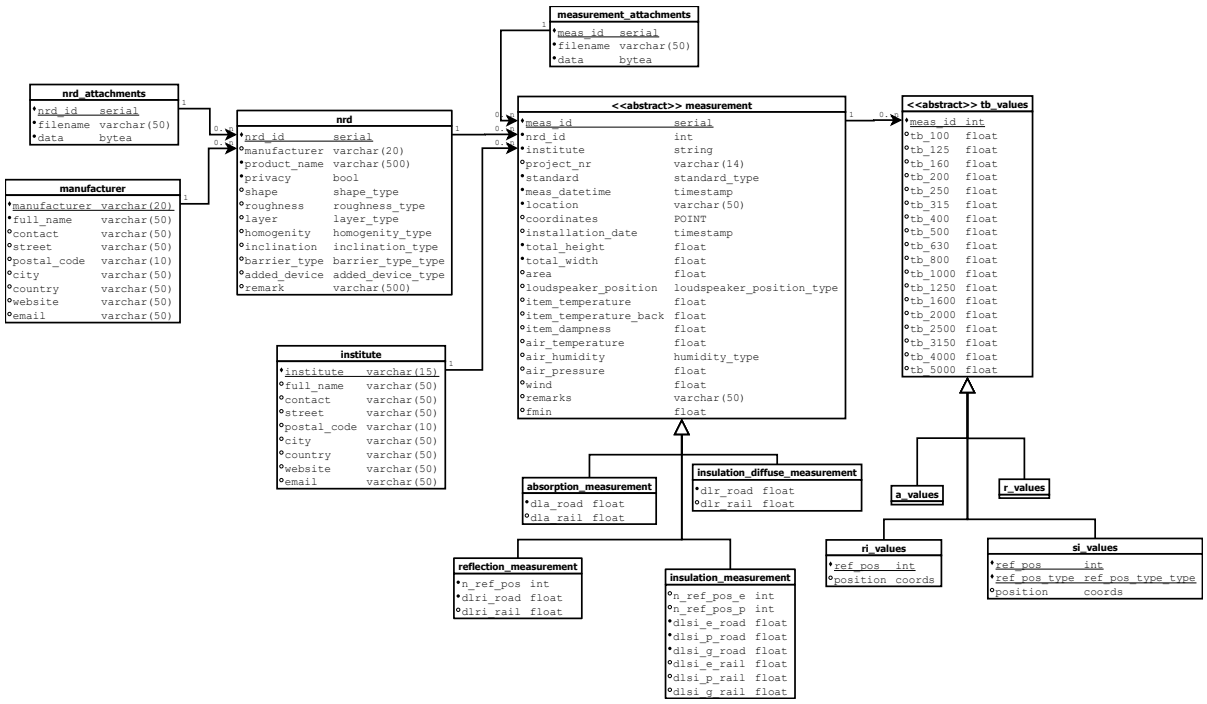

Figure 2: Entity–relationship model of the SOPRANOISE database [©AIT]

The third objective is to establish up to what extent the acoustic degradations could affect / reduce the global noise barrier performance (insertion loss): this will allow to better understand the long-term performances of noise barriers to reduce noise: this task is in current progress, it considers the two following approaches:

- In the first approach, a theoretical model is used to calculate to what extent common "simple leakages" could affect the insertion loss (see figure 3) : with a systematic batch of calculations for the most relevant types of leakages, a catalogue based on geometrical parameters has been produced. The catalogue can be extended and customised to cover the relevant cases and draw conclusions about when the impact of a leakage is negligible or when further actions are necessary. With the knowledge of this catalogue and practicing in real life, a fast assessment of the current effectiveness of a faulty noise barrier will be possible.

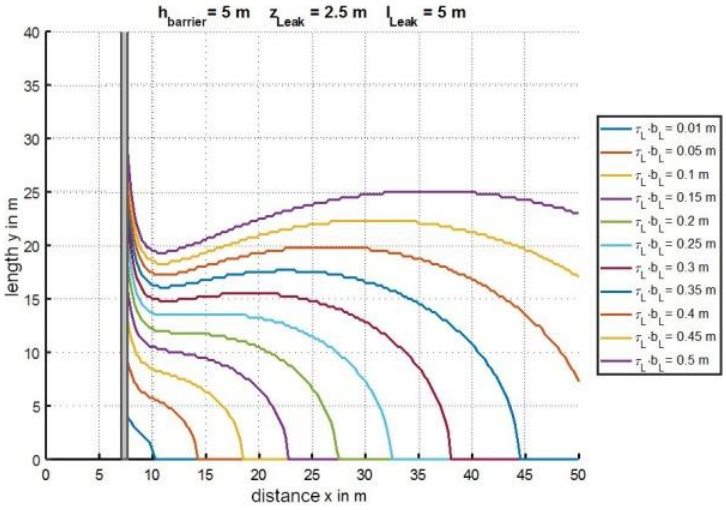

Figure 3: Calculated radius of influence for a vertical rectangular leakage of length $l_{Leak}=h_{barrier}$ with different effective width $\tau_L \cdot b_L$; barrier height $h_{barrier}$; average leakage height $z_{Leak}= 1/2\_h_{barrier}$ (adapted from [8])

- The second approach deals with the dependency of the noise barriers performances on its intrinsic sound absorption / reflexion, and airborne sound insulation characteristics; this task is currently running: the effect of degradation of intrinsic performances is analysed for typical situations. The study considers commercial sound propagation software for simple cases, while multiple interactions will be detailed with FEM program.

5. WORKPACKAGE 3: IN-SITU INSPECTION TOOLS

To characterize the intrinsic acoustic performances of noise barriers from the easiest (but possibly the least accurate) way up to the most accurate one (but possibly being quite long, difficult and costly), SOPRANOISE proposes the following "engineering progressive approach" with the following 3 successive steps: (1) in-situ inspections – (2) quick methods – (3) full methods. At the end of each step, relevant decisions could be taken whether fair conclusions can be drawn or if further tests are still necessary or not (see figure 4).

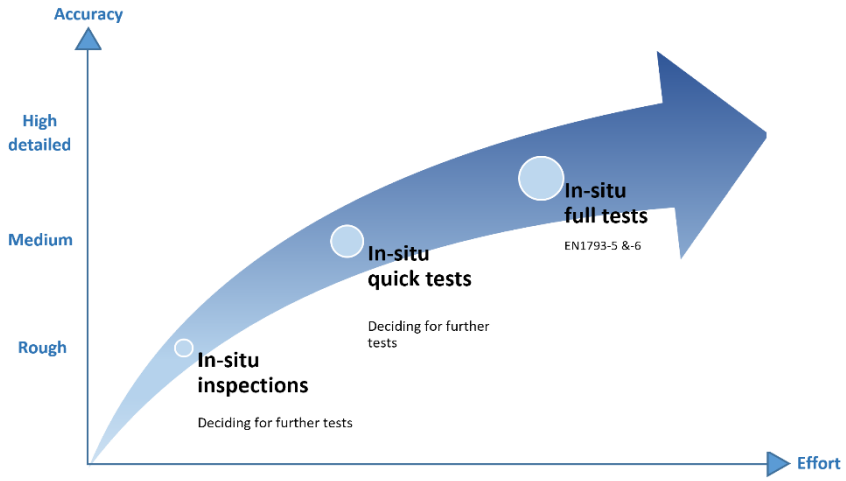

Figure 4: SOPRANOISE progressive 3-steps approach to characterize installed noise barriers [©SOPRANOISE]

The fastest tools are in-situ inspections with visual and aural checks: while almost qualitative, they can spot out major defects and give information on the possible sites to be further investigated. SOPRANOISE aims to establish up to what extent those in-situ inspections can yield fair conclusions on the noise barriers acoustic performances / conformity.

European existing in-situ inspection methodologies will be analysed and reported. Partner BASt has a database of the whole German road infrastructure network, including noise barriers: suitable existing noise barriers that could allow investigations on common defects to develop a proposed practical inspection tool are currently analysed. First contacts with different road administrations doing regular inspection routines have been already started, but the procedure has been unfortunately slowed down by COVID-19.

The cross-comparison of data extracted from the database (WP2) and the information coming from in-situ inspections (WP3) will allow to draw considerations and trends to understand the effect of acoustical degradation of noise barriers for different scenarios (e.g. road or rail, barrier type, height, geographical location etc.) with advices and things to avoid.

This degradation effect on the overall noise barriers acoustic performance will then be carefully considered and documented to objectively understand the long-term ability of noise barriers to reduce road noise: The final aim is to submit the new validated in-situ inspection methods and tools to standardization.

6. WORKPACKAGE 4: QUICK AND SAFE METHODS ALONGSIDE ROADS

Initially drafted for certification, EN1793-5 [1] and EN1793-6 [2] methods can be, and are today used for in-situ testing of noise barriers; WP4 aims to revise those in order to (non-exhaustive list):

- Simplify the equipment (lightweight microphones / grid / loudspeaker), in order to make it more portable in close proximity of noise barriers alongside roads or railways;
- Improve the signal processing in line with current research trends not yet implemented in the published EN standards;
- Develop a simple, self-contained procedure, easy to implement in software, in order to have the most automated tests, thus limiting the need of expert users;
- Limit the dimensions of the system for safety reasons and to minimize traffic disruption;
- Assess the reliability of the methods in comparison with EN1793-5 [1] and EN1793-6 [2], and fix how to conclude with the corresponding results (e.g.: totally good, totally bad, or in between good and bad, when more accurate tests are necessary).

These major improvements will be at first tested in the laboratory and then, when deemed sufficiently robust, on real-life noise barriers installed alongside roads. The quick methods will thus be designed, checked in the laboratory, and finally validated in-situ in order to have a practical tool for an on-site conformity check of a whole noise barriers. Those “quick and safe” measurements could then be carried out during, or shortly after, the construction phase. The final WP4 aim is to submit this method to the CENTC226/WG6 (roads) and TC256/SC1/WG40 (rail) for standardization.

At the date of writing this paper, a State of the Art of potentially interesting measurement methods for sound absorption and airborne sound insulation has just been finalized, it considered:

<u>For sound absorption</u>:

- Methods using a p-u probe (Microflown);
- Methods using an impedance tube;
- Methods using sound intensity techniques;
- Methods using beamforming techniques;
- Other methods, and
- Single-microphone QUIESST procedure (as EN1793-5 [1] and EN1793-6 [2]) (see figure 5).

Figure 5: portable device for measuring sound reflection [©AIT, unpublished]

For airborne sound insulation:

- Methods using beamforming techniques, and

- Linear antenna scanning (see figure 6).

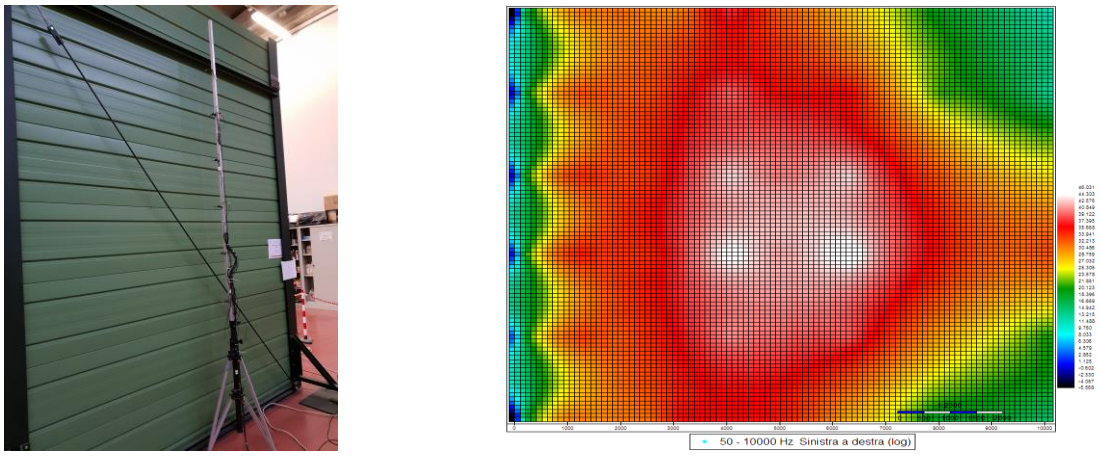

Figure 6: Left: prototype antenna. Right: free-field measurement on the loudspeaker; x-axis: frequency (from 50 Hz to 10 kHz); y-axis: measurements from the 6 microphones [©UNIBO, unpublished]

The intermediate report presents a comparison of the pros and cons of those "candidates" methods: this will be included within the presentation.

7. WORKPACKAGE 5: FINAL REPORT AND GUIDELINES

This work package will give practical guidance on noise barriers for road and railway authorities to ensure appropriate consideration of the acoustic properties at different stages and situations: a holistic approach is proposed for designing new noise barriers projects, as presented at figure 7.

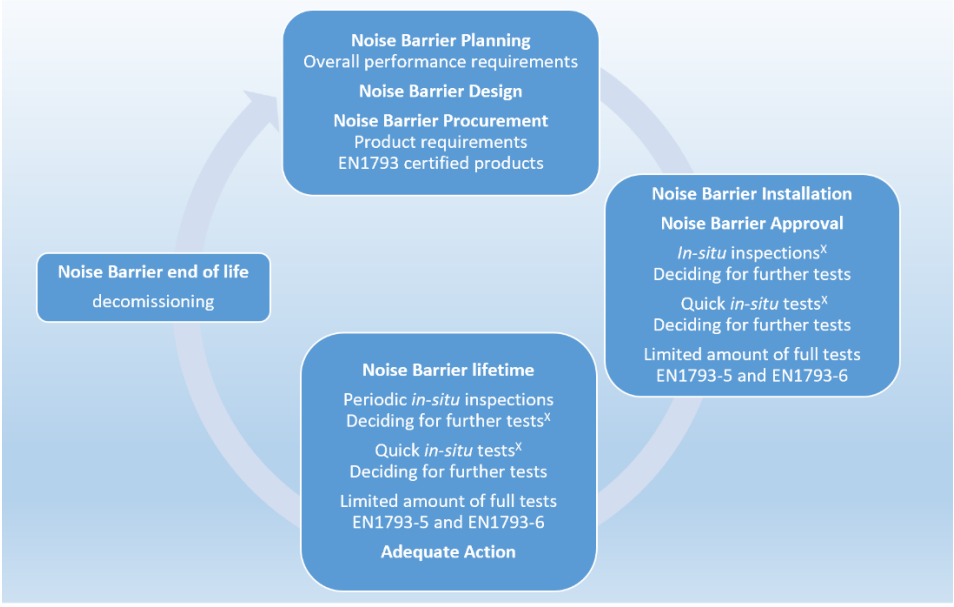

Figure 7: SOPRANOISE proposal for a holistic approach of noise barriers projects (x: in-situ inspection tools and quick in-situ tests will be proposed to standardization) [©SOPRANOISE]

This includes:

- planning stage (recommendations of minimum requirements for insulation and absorption values for different situations);
- procurement stage (request of and interrogation of Declaration of Performance and CE marking, where required - Procurement Pass or Fail)?;
- sustainability of the product, approval criteria;
- approval upon arrival on site, installation (including competence of installers), on site testing, approval or rejection and associated contractual management of this issue considering risk management;
- long-term performance, including monitoring (acoustic and visual) regime and guaranteed performance;
- decommissioning stage.

The new tools developed will be published on a dedicated website (SOPRANOISE website is already started but contains limited data, as of today: https://www.enbf.org/sopranoise/) to promote the content of this project to road and rail authorities, manufacturers and other stakeholders, the scientific research community and the wider public.

4. CONCLUSIONS

SOPRANOISE research aims a better understanding on how to use noise barriers alongside road and railway networks by characterizing those in the easiest way throughout their lifetime. At the end of the research, a clear and effective practical guideline for the assessment of noise barriers at different stages will be published. This will include: (a) a comprehensive and understandable overview of the physical relations and differences between in-situ and laboratory measurement data on noise barriers, and (b) a new quick and safe method which closes the gap between first rough in-situ inspections (visual and aural) and the application of the full barrier test methods according to EN1793-5 and EN1793-6.

This 3-steps approach allows road and rail authorities to consider noise barriers in the most cost-effective manner and avoid extensive measurements when there is no need of (figure 4).

5. ACKNOWLEDGEMENTS

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6. REFERENCES

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