

THE CONTRIBUTION OF STANDARDS AND STANDARDIZATION IN ACHIEVING ACOUSTIC COMFORT

UDC 534:614

Dragan S. Cvetković

University of Niš, Faculty of Occupational Safety in Niš, Serbia

ORCID iDs: Dragan S. Cvetković

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Abstract. *Acoustic comfort in the context of the harmful effect of noise on human health in the living space of a residential building can be viewed based on the definition of the World Health Organization (WHO), according to which health is "a state of complete physical, spiritual and social comfort". According to this definition, health action includes both increased subjective comfort and physical health damage, which over time may result in physical health damage. This paper offers one point of view in an attempt to improve the process of establishing evidence of exposure to noise in the living space of a residential building and to support a more impartial presentation of data regarding the negative effects of disrupting acoustic comfort with contents that violate privacy and human health. The growing influx of complaints about the phenomenon of noise in the environment, as well as its impact on mental and physical health, requires a higher level of professional attitude towards a complex-multidimensional problem and a layered analysis of the spectrum of negative effects that imply sleep disturbance, auditory and extra auditory disturbances. Achieving acoustic comfort is a complex, multi-functional problem, which includes numerous external and architectural factors such as: the purpose of living space, the nature of noise in the environment, and acoustic values of building structures and materials. Unfortunately, numerous examples of "bad practice" are known, where the owners-buyers noticed all construction defects hidden under the luxurious surface only after moving in, and the largest number of customer complaints is related to acoustic comfort.*

Key words: *noise, acoustic comfort, customer satisfaction, public health*

Received September 20, 2024 / Accepted October 21, 2024

Corresponding author: Dragan S. Cvetković

University of Niš, Faculty of Occupational Safety in Niš, Čarnojevića 10a, 18000 Niš, Serbia

E-mail: dragan.cvetkovic@znrfak.ni.ac.rs; dcdbest@gmail.com

1. INTRODUCTION

We have witnessed more intensive construction of residential buildings in the last two decades. Construction is particularly intensive in large cities, and in addition, the price per square meter of residential space is constantly increasing, and real estate sales are booming. Buyers are ready to pay significant amounts of money for their "four walls" and rightfully expect high quality in return. Unfortunately, buyers of new apartments complain most frequently about acoustic comfort. What should you do if you've already moved into a noisy apartment and how can you stop this behavior? Objectively, numerous examples of "bad practice" are known where buyers only notice all construction defects hidden under the luxurious surface after moving in. People keep commenting: "I paid thousands of euros for a square meter and I hear my neighbor talking on the phone, snoring while sleeping, how many times he uses the toilet during the night, etc." The explanation of the term "acoustic comfort" is based on the meaning of the term "comfort", which implies comfort, ease, as well as everything that makes life comfortable and pleasant. However, if we ask ourselves what kind of comforts there are when it comes to housing and what is actually "acoustic comfort"? The answer could be derived from the Rulebook on Buildings Energy Efficiency, which considers potential comfort conditions necessary for living comfort, consisting of four basic prerequisites: thermal, air, visual and acoustic comfort. According to the aforementioned viewpoint, acoustic comfort represents conditions in which the level of noise in the living space is such that it does not cause a feeling of discomfort. Good acoustic comfort does not mean achieving complete silence in the housing unit, which in itself can often be unpleasant, but achieving an acceptable level of noise from the outside environment and the immediate environment. In other words, the sounds coming from the hallway, neighboring apartments, or the outside environment must be reduced to a level that in no way disturbs privacy and the daily rhythm of life.

The quality of sound insulation in the "living space" is becoming a more frequently asked question as a result of the growing demands of real estate buyers and users, both in terms of lowering noise levels from the surroundings and from installations within the building. Achieving the required level of acoustic comfort is a technologically complex task, which includes numerous external and architectural factors: the purpose of the building, the acoustic zone of the location, the spectral content of noise in the environment, the use of building systems and materials, the design skills in the materialization of these requirements, the implementation and compliance with standards in order to meet the needs for the comfort of residential space users.

Buyers who spend more and more money on real estate are likely to have higher expectations and demands in terms of sound comfort given the upward trend in the price of square footage of residential space on the domestic real estate market. In practice, unfortunately, providing adequate acoustic comfort is not in the interest of those who define construction conditions; however, it should be in the investor's interest. In the case of the former, the reason is a lack of expertise and insufficient knowledge of the problem, and in the case of others, it is material interest, because acoustic quality costs money.

Acoustic comfort is defined as a psychophysical state where an individual feels good about a particular activity in a particular setting, which implies:

- Protection against noise, because noise is defined as any unwanted sound, so acoustic comfort means providing protection against sound disturbance originating from sources outside the building and inside the building;

- Protection of privacy, because it implies the provision of protection against eavesdropping between rooms, that is, spaces; and
- Adequate quality of the desired sound content, which means ensuring adequate acoustic quality of rooms or spaces in accordance with the requirements of the quality of the sound image (intelligibility and aesthetics).

Unfortunately, in reality, acoustic defect solutions are typically only sought after after the object is completed and the acoustic defects are felt during the use phase of the space in public places like offices, meeting rooms, hospitals, schools, children's institutions, etc.

2. WHY ACOUSTIC COMFORT IS IMPORTANT

Noise as a phenomenon of acoustic activity unequivocally has a negative impact on human health and well-being, and at the same time, it encourages the scientific and professional public to be more and more concerned in the search for acceptable solutions in protection. The latest report from the European Environment Agency (EEA) [1] confirms that exposure to noise has an important impact on people's mental and physical well-being. It is estimated that noise pollution affects at least 20 % of the European population living in urban areas where the level of noise generated by traffic (road, rail and airplane) is harmful to people's health. It is also estimated that in Europe over 113 million people are exposed to long-term noise levels from road traffic during the day and night period (L_{den}), with a value of at least 55 dB. To this data should be added the fact that in Europe, according to estimates from 2020, 80 % of citizens live in or near cities. [2] with increased demand for road, rail and air transport. Simultaneously with the increase in noise sources, one can expect increased exposure and associated adverse health effects. Noise was found to be the cause of 48,000 cases of chemical heart disease, and 12,000 cases of premature death. According to estimates from the EEA – European Environment Agency report, 12,500 European students suffer from learning disabilities resulting from noise generated by air traffic. Seen through the prism of time and the activities undertaken, the number of people exposed to noise sources has been stable from 2012 to the present day, which can be assessed as not achieving the main goal of the vision of the Environmental Noise Directive 2002/49/EC for the year 2020, "that not a single person should be exposed to a level of noise that can endanger health and quality of life".

According to the literature reviewed for this study, there are four key non-physical factors that influence the perception of noise in the environment: work activity; context and attitude; perceived control and predictability; personality and mood [3].

The interpretation of the sound that has taken on the phenomenon of "noise" depends on the personality and a number of other dependent factors and circumstances. This means that individual people will react differently to the same acoustic challenges in their environment, which is another reason for layered consideration of noise disturbance and valuing individual differences in the context of acoustic content in order to reach the required level of "acoustic comfort".

Making a conclusion about the harmfulness of noise to human health must first take into account noise sensitivity, which is based on general attitudes about noise [4,5] and is an important variable for explaining the discrepancy between exposure and individual anxiety response. This fact raises the question of whether individuals who are sensitive to noise are simply those who complain more about their environment.

Health, as a valuable asset, deserves legal protection, and that is why national legislation has a responsibility to regulate the requirements related to sound insulation, which is a prerequisite for acceptable "acoustic comfort", by law and under legal regulations. In the comments of the legal doctrine, it is stated, among other things:

- that the intimate area is specially protected, which includes the sphere of human life characterized by great isolation from the engagement of other people (with the exception of the family).
- that the apartment in the narrower sense is part of the private, intimate sphere. Bearing this in mind, the need for the inviolability of the home to be a right that aims to guarantee the individual the "elementary quality of living space", the right "to enjoy peace", in terms of his human dignity and in the interest of personal free development, is strengthened.

When it comes to ambient comfort: "The building must be designed and built so that the noise felt by the occupants or people nearby is kept at a level that is not dangerous to health and in which satisfactory conditions are provided for night rest, leisure and work." Acoustic comfort in buildings is achieved if unwanted sounds (noise) are not noticed, if people's privacy is ensured, which means that their activities cannot be heard by the environment, and if everything that is wanted to be heard, for example, speech, is recognized and understood without effort (when desired) [6, 7]. In order to achieve this, the construction facilities must provide:

- adequate sound insulation from airborne and structural sound inside the building,
- adequate insulation of the facade, which ensures an acceptable level of ambient noise coming from the outside environment,
- a system of installations in the building that does not produce noise and does not impair other measures to achieve sound comfort,
- privacy in areas where it is necessary,
- adequate acoustic response of interior spaces that determines the sensibility and quality of useful sounds.

To increase satisfaction, classifying "acoustic comfort", which is a very pronounced subjective component, must rely on standards and respect for construction technology (selection of location, purpose of the building, materialization of the architectural project, control over construction processes) in order to increase the level of satisfaction.

3. STANDARDS AS A PREREQUISITE FOR ACOUSTIC COMFORT

In today's living conditions and associated risks, as discussed in the introduction to this paper, "acoustic comfort" has become an unavoidable segment of our reality, especially in the spaces where we spend the most time, the place where we live or work (apartment or office). It is not a rare case that being in an office, restaurant, hospital, hotel, industrial plant, cinema, swimming pool, kindergarten or your child's school is a place where the acoustic content in the environment did not please you and you experienced it as noise [8].

Acoustic comfort is a concept that refers to the quality of sound in a certain space and its impact on the subjective experience of people staying in that space. This concept includes various factors, such as the noise level, the type of sounds present in the environment, the acoustic properties of the materials in the space, and the ability of the space to absorb, reflect or isolate sound.

Ideally, an ambient space is expected to have an optimal acoustic quality that allows people to communicate effortlessly, to relax and concentrate without distraction and to have a pleasant experience of being in that space. This can be especially important in different environments such as offices, classrooms, restaurants, concert halls, hospitals or homes. Maintaining acoustic comfort can involve the application of various techniques such as the use of acoustic materials, designing spaces with optimal acoustic properties, using sound insulation systems, or implementing noise reduction strategies.

Sound insulation standardization is a key element in ensuring "acoustic comfort" - sound quality in construction projects. International organizations for standardization (ISO, EN) as well as national institutions of the most developed countries in Europe create the necessary but not sufficient conditions for achieving the final goal of complete acoustic comfort:

- German Institute for Standardization DIN – "Deutsches Institut für Normung"; Sound insulation is considered in DIN standards through various aspects to ensure that buildings and construction materials meet certain standards for noise protection. The first version of the standard sheet DIN 4109 "Sound insulation in construction", which is still valid today, was published in 1944. DIN 4109 provides the basis for the calculation and gives the minimum specifications for sound insulation. The main goal is to protect health [9]. The minimum sound insulation provided by the DIN 4109 standard has always been considered a way to prevent unreasonable noise during normal life habits. However, this is often not enough in terms of today's user requirements, user behavior, and lifestyle. In order to meet the demands of planners and users who want more than minimum sound insulation, recommendations for increased sound insulation were already included through the 1962 version of DIN 4109, and DIN 4109 from 1989, which is valid today, in the supplementary sheet contains and 2 recommendations for increased sound insulation. However, the values there are so strongly characterized by compromises that the recommendations for increased sound insulation sometimes differ only slightly from the requirements of DIN 4109, and therefore there is no subjectively significant improvement. DIN 52210: "Testing of sound insulation in construction – Testing at the place of application." It provides guidelines and procedures for measuring the sound insulation of materials and structures in real buildings to verify compliance with the specifications in DIN 4109.
- The VDI (Verein Deutscher Ingenieure) is an association of German engineers that also develops technical guidelines and standards, similar to the German Institute for Standardization (DIN). When it comes to acoustics in buildings, VDI also has relevant standards and guidelines. One of the most important VDI standards related to acoustics in buildings is VDI 4100. This standard covers various aspects of acoustics in buildings, including the design and measurement of sound insulation, noise control in interior spaces, as well as criteria for assessing acoustic comfort. The VDI 4100 provides guidance on how to achieve an appropriate level of acoustic comfort in different types of rooms, such as offices, schools, hospitals, hotel rooms and the like. It also provides guidance on materials and constructions used to improve sound insulation and absorption within buildings.
- DEGA – The German Society for Acoustics, "Deutsche Gesellschaft für Akustik", carries out accreditation or certification that confirms that a product or service meets certain standards in the field of acoustics. DEGA is a renowned organization in the field of acoustics, engaged in research, development and promotion of acoustic sciences and technologies. Their standards and guidelines are often used in the

industry to ensure acoustic quality in various environments, such as music rooms, concert halls, offices, or industrial spaces. However, in the field of acoustics, there are different approaches and classifications that can be used to categorize objects according to their acoustic properties. For example, buildings can often be classified according to their purpose and specific requirements for acoustic comfort. This may include the classification of facilities such as concert halls, cinemas, offices, schools, hospitals and the like, with each type of facility having its own specific acoustic needs.

- The French Institute for Standardization "AFNOR – Association Française de Normalisation" publishes the French standards "Normes Françaises NF", One of the most famous French standards related to sound insulation is NF S 31-080: This standard specifies methods for measuring the sound insulation of walls, of floors and ceilings in buildings. It also provides guidelines for the design and installation of sound insulation in buildings with ISO international standards and is often used in French construction projects. These standards specify how to measure a building's acoustic performance and assess its sound insulation through acoustic tests on building components and structures, including sound insulation measurement.
 - In Great Britain, "British Standards Institution – BSI" is the institution from which the most famous standards for sound insulation originate. Several key British Standards relate to sound insulation: BS 8233: a standard that provides guidance on the design of sound insulation in buildings to provide a comfortable environment for occupants. It includes factors such as external noise, internal noise, vibration and acoustic comfort. BS 4142: standard which defines procedures for measuring noise from industrial, commercial and recreational sources, and their impact on surrounding buildings and residents. Although it does not focus exclusively on sound insulation, it provides guidelines for assessing noise levels and their impact. BS 6472: standard specifies procedures for measuring vibrations transmitted through ground and structures in buildings. Vibrations can be a source of discomfort and disturbance, so their measurement and control are important for maintaining acoustic comfort. BS EN ISO 717: a series of standards defining procedures for measuring the sound insulation of walls, floors, and ceilings in buildings. All of the standards listed are aligned with international ISO standards and are often used in UK construction projects.
- BREEAM (Building Research Establishment Environmental Assessment Method) is a building sustainability rating system used worldwide to assess the environmental performance of construction projects. This rating system was developed in the UK by the Building Research Establishment - BRE to promote sustainability in the construction industry. BREEAM, as a building sustainability rating system, also considers acoustic comfort as part of its rating criteria. Acoustic comfort plays an important role in the quality of life of building users, so it is important to take this area into account during the design, construction and management of buildings. As part of the BREEAM assessment, acoustic comfort usually includes the following aspects:
- Sound proofing: This refers to the ability of a building to prevent the transmission of sound between rooms or between the interior and the exterior. BREEAM assesses the sound insulation quality of materials, structures and installations to ensure that privacy is maintained and disturbance from outside noise is reduced.
 - Sound absorption: This aspect refers to the building's ability to absorb sound inside the premises, thereby reducing reverberation and improving acoustic

comfort. This may include the use of acoustic materials and room design that reduces echoes and noise.

- Room acoustic design: BREEAM also assesses the planning and design of rooms to ensure that optimal acoustic comfort is achieved for building users. This may include strategies such as proper speaker positioning, reverberation and noise control, and the use of acoustic screens or baffles.

In our country, the Institute for Standardization of Serbia is a national standardization body, which, among other things, adopts, develops, reviews, changes, supplements and withdraws Serbian standards and related documents; ensures compliance of Serbian standards and related documents with European and international standards and related documents.

In the field U 043 "acoustics in construction", the current number of standards that are available to the public is 151, (published standards, standards for which the review procedure has been completed, and standards for which the review procedure has begun), and the number of new projects is eight.

The existence of standards has created conditions for design, construction and control processes to be carried out without restrictions, for sound insulation to be performed in compliance with accepted construction technology guidelines and in a manner that ensures "air and structural" sound insulation in and around buildings is a reliable guarantee "acoustic comfort" for the benefit of the tenants' health. Unfortunately, one gets the impression that listening to the ambience of significant architectural achievements, the materialization of the space was realized without a sense of how that space will sound and how many chances it will give us to enjoy it with all our senses.

By definition, a standard is a document that provides conditions, specifications, guidelines, or characteristics that can be used to ensure that materials, products, processes and services are fit for purpose. Standards are established by consensus and approved by recognized bodies. The application of Serbian standards is voluntary, which means that there is no automatic legal obligation to apply them. However, laws and technical regulations may refer to standards, making compliance with them mandatory.

Disputes over acoustic comfort and sound insulation as disputed facts demonstrate that the standard is necessary but not decisive in achieving the goal. In the country where the first DIN standard was published in 1938 and determined the minimum level of sound insulation required by construction legislation, it has no influence on current judicial practice. The current version of DIN 4109 from 2018 does not contain any requirements for increased sound insulation. In Part 5 - DIN 4109, increased noise insulation was developed as a continuation of Appendix 2 and published in 2020. Market acceptance will become evident in the coming years. The update of DIN 4109, from a legal point of view, has no impact on current court practice. This is because the Federal Court of Justice (BGH – Bundesgerichtshof), in its judgment of June 14, 2007 - VII ZR 45/06, BG HZ 172, 346, does not base its judgment on the requirements for sound insulation according to DIN standards, but on what are noise insulation level agreed by the contracting parties. In the verdict BGH VII ZR 45/06 of 14.06.2007. the position of the court is that:

- Requirements for sound insulation are subject to dynamic changes. On the one hand, they are based on people's current needs for peace and individual isolation in their own living space.
- On the other hand, they depend on the ability of construction and the construction industry to provide the widest possible noise protection, taking into account the economic interests of both contracting parties.

- Dimensions of sound insulation specified in private technical regulations cannot be used as recognized rules of technology if there are economically acceptable construction methods that comply with recognized rules of technology and which easily achieve greater dimensions of sound insulation.

4. HOW TO ACHIEVE SATISFACTION AND ACOUSTIC COMFORT

The fact that the national legislation, as well as the technical regulations, do not recognize the concept of "acoustic comfort", does not mean that it is less important and that it cannot be the subject of consideration and dispute, because the threat of noise in the living-residence area is an undeniable fact, which is easily proven, and derives from the END - Environmental noise directive 2002/49/EC, Serbian Law on Environmental Noise Protection and other positive laws that address noise as a phenomenon, particularly its subjective aspect.

Scientific experts emphasize the existence of four key non-physical factors that influence the perception of noise in the environment: - work activity; context and attitude; perceived control and predictability; personality and mood. The interpretation of a sound as "noise" depends on personality and a number of other factors and circumstances. This means that individual people will react differently to the same acoustic challenges in their environment [10]. This is another reason for layered consideration of noise disturbance and valuing individual differences, through the context of acoustic content.

On the basis of their personal, scientifically professional knowledge and skills in relation to noise in the environment, after studying the contents of documents from the literature [11,12], the experience achieved in improving acoustic comfort in accordance with the explicit request of the civilized needs of the users of the residential space in relation to the existing practice, they impose directions thoughts:

- The expected level of acoustic comfort depends on the precision of the agreed level of sound insulation from noise between the designer-contractor and the client.
- Compliance with the minimum sound insulation standards is not sufficient in the civil law sense, but only the construction works performed at the time of acceptance, which corresponds to judicial practice.
- Responsibility for an inadequate level of acoustic comfort cannot be avoided, regardless of the fact that in the chain from the purchase contract to the handover of the real estate, omissions are made in the interest of the investor, and to the detriment of the buyer.

The only question is, which mechanisms in construction have lost their function and how to assign them a management structure in order to transform an inert system from a "pathological" into a proactive construction system, which seeks the interests of the customer.

It is difficult to explain why, in reality, the contract for buying apartment defines the purchase of an "area in m²" of residential space without providing any information regarding the structure's acoustic performance, despite the fact that Article 3a of the Law on Planning and Construction mandates: "Technical documentation ensures that the building as a whole, i.e. individual component, should be suitable for the intended use, and that the building satisfies the following fundamental requirements during an economically viable period of use: point 5 noise protection", but with details about the choice of ceramics, parquet, side of the world, etc. The sales contract is usually prepared by the investor and offered to the buyer on a "take it or leave it" basis.

It is difficult to explain that in the first step of the project implementation, known as "Information on the location for the cadastral plot", the investor is not informed in which acoustic zone the cadastral plot is located, despite the fact that every local community is required to implement environmental protection measures against noise: acoustic zoning, determine quiet zones, as well as prohibit and limit measures on its territory and that by the decision of the competent authority, in accordance with the Law;

Also, it is difficult to explain the fact that the project for obtaining a building permit does not contain a Study on the sound protection of the building, even though it may be a school, kindergarten, senior living facility, hospital, etc., and can be located in one of the five acoustic zones, which is clearly not in accordance with the Law on Planning and Construction.

Furthermore, it is hard to explain that the same object is subject to acoustic tests even though there isn't a single detail in the documentation from the conceptual project to the completed project that takes into account any acoustic issues. On the other hand, it is a problem to prove that the noise issues have been dealt with, if there are no valid records in the project and construction documentation.

There is a question of how to explain the fact that the noise phenomenon mentioned in the Rulebook of requirements and standards for residential building and apartment design ("Official Gazette of RS", no. 58/2012, 74/2015 and 82/2015) is considered only in relation to the provisions of Article 30 "All rooms in which noisy facilities are located (diesel generators, boiler rooms, hydropower stations, heat transfer stations, machine room, driving shaft, ventilation drive equipment, etc.) cannot border residential premises and must be isolated from the structure buildings".

What kind of acoustic comfort can be expected in an expensively paid square meter of an apartment, if the investor appoints the committee for technical inspection? It is important that the members of the committee are persons who have design licenses, and that no examination of the acoustic values of the constructed structures is carried out and that proof of the soundproofing of partition walls, between floor structures, windows and entrance doors is not presented.

It is difficult to accept the fact that all the windows in the building are of the same construction and with the same glazing, regardless of the orientation of the facade and sources of noise from the environment. Also, the entrance door is of the same construction regardless of whether the entrance to the apartment is next to the elevator or next to the entrance to the building. Usually, during the handover of the residential space, the Apartment Condition Report is signed, without a single record of issues that need to be fixed and refers to electrical installations; water installations; sewerage, sound insulation of the facade; windows; partition; energy efficiency passport.

The legalization of the JUS standard in J6 201 in the Rulebook on technical norms for the design and execution of final works in construction ("Sl. list SFRJ", no. 21/90) created catches that the subject of the standard: "This standard establishes the technical conditions that must be met: a) during design, b) during construction or reconstruction, c) when testing sound protection during the reception of buildings intended for human habitation". The provisions of this standard are also applied to the reconstructed parts of the building, as well as to rooms whose purpose has been changed") be mandatory. Realistically, today, after 34 years, there is no trace of such an obligation in Serbian construction.

This situation dissuaded many institutions from giving up the accreditation of the method for field measurement of sound insulation, although they invested significant funds for the purchase of rather expensive equipment, for personnel training and accreditation.

And that's not the end, on August 25, 2015, the Deputy Prime Minister signed the Decision stating that "A working group is being formed to draft a proposal for a regulation on sound comfort in buildings"; however, there is no Regulation. Given that trust is gained through long-term results as evidence of dedication to work, and distrust does not require proof, only suspicion is sufficient. There remains a doubt that some interest has overcome the need, so pleasure and acoustic comfort will have to wait until a new century.

5. CONCLUSION

It stands to reason that the investor should assess the degree of construction from the standpoint of sound comfort in the same manner that the buyer chooses the size of the apartment or the quality of the bathroom ceramics. This statement is supported by the consequences of mass housing construction in Serbia in the last ten years, as well as the way of life; therefore, sound comfort has become a serious design, engineering-scientific, economic and sociological challenge. Acoustics, as one of the engineering disciplines in the design and construction of buildings, has the task of ensuring the expected level of sound comfort in the built space. That specific type of comfort has several dimensions:

- That the person in the apartment is not disturbed by sounds coming from the outside environment and from neighboring rooms, as well as that the sounds produced do not disturb other people in and around the building. In this way, the desired and necessary privacy is ensured.
- To enable quality sound communication in rooms where necessary, which implies good intelligibility and audibility of speech and music.

Unlike other engineering disciplines in the design process, regulations based on standards cannot be an absolute guide for all details important for sound comfort. It is expected that the customer has the right to demand a sound comfort level higher than the minimum prescribed by the regulation. This naturally follows the task of the designer to seek the help of an acoustic consultant to consolidate and optimize the requirements in the initial design phase in order to achieve a successful design outcome, to the satisfaction of users and investors.

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