

## The role of indoor soundscape methodology: From architectural design process to establishment of regulations

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### ABSTRACT

One of the most important research field to enhance the environment is "soundscape" that concentrates on urban and indoor sound environments, with a focus on improving the quality and pleasantness. The ability of designing sustainable soundscapes and the necessity of it, have led to a new discussion in standardization of soundscapes. Most of the detailed work of the working group on perceptual assessment of soundscape (ISO/TC 43/SCI/WG 54) focuses on soundscape quality, analysis methods and parameters on open public spaces. However, indoor soundscaping, which is a more recent research topic is as important as the urban soundscape because people spend 80% of their time indoors. Therefore, its standardization and application in the architectural design process is very crucial to improve indoor soundscape quality. In this study, present policies and applications about noise management and soundscape are assessed and international regulations are compared. In addition, deficiencies in both national and international regulations regarding indoor soundscaping, and promising leading role of standardizing indoor soundscape methods and factors to be used in architectural design process and the establishment of related regulations are discussed.

Keywords: Soundscape standardization, Noise regulation, Indoor soundscaping, Soundscape factors

### 1. INTRODUCTION

Progressing soundscape studies reveal a discussion about if noise management policies, regulations, and action plans are sufficient to attain the preferable and healthy acoustic environment. The most significant evidence that leads to reveal this discussion is different attitudes of noise management and soundscape towards sound. While noise management considers only unwanted sounds and negative effects of noise, soundscape approach conceives sound as a resource and focuses on sounds of preference. In addition, with the regard of action plan, noise management approach deals with reducing sound levels of unwanted sounds, but soundscape approach manages positive sounds besides masking unwanted sounds (1). In other words, noise management mostly attends to physical measurements of sound, however this measurements are not useful for determining the preference of people on soundscape (2).

Since soundscape means "acoustic environment as perceived or experienced and/or understood by a person or people, in context"(3), it has a direct relationship with human perception and the environment around, and this arises many factors to be dealt with in application and design process besides acoustical measurements. Because soundscape is a multi-factorial context, it is needed to be standardized and well explained as possible in order to operate properly in design process. The first attempt of soundscape standardization was presented by International Organization for Standardization (ISO). In 2008, ISO established a new working group named "perceptual assessment of soundscape quality" (ISO/TC 43/SCI/WG 54) and published the first part of the standardization "ISO 12913-1:2014 Acoustics-Soundscape-Definition and conceptual framework" in 2014. However, this standardization is about open public spaces of urban soundscape quality, methods and factors thereby there is still a gap regarding standardization of indoor soundscaping.

To develop a possible proposal on the indoor soundscape standardization or regulation, present noise regulations, standards that are included in related regulations and noise guidelines are needed to be reviewed. The regulations/directives and guidelines of European Union (EU) and Turkey are

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analyzed and compared under the scope of this study. In addition, since soundscape factors and methods have an essential role on architectural design process of indoor soundscape, they are needed to be analyzed to discuss the possibility of standardization.

## **2. SOUNDSCAPE IN APPLICATION AND DESIGN PROCESS**

To compile the principles of indoor soundscape, it is rather crucial to analyze and understand the present International Organization for Standardization (ISO) standard 12913-1:2014 (3) about urban soundscape. Starting from the scope of ISO standard 12913-1:2014, indoor soundscape factors and methods can be formed in a proper frame. However, since the scope of ISO 12913-1:2014 is on urban scale, it will be inadequate for indoor soundscape assessment. Hence, several studies on soundscape factors (1, 3-8) and methods (4, 9-11) are needed to be evaluated to gather more information about indoor soundscaping principles.

### **2.1 Standardization of Soundscape**

The published standard of ISO about urban soundscape has aimed to present definitions related to subject, and the factors interacted and influenced each other in context. Seven main concepts were presented as “context, sound sources, acoustic environment, auditory sensations, interpretation of auditory sensations, responses and outcomes” in order to define the process of “understanding” or “perceiving” the acoustic environment (3). These seven concepts and their relationship with each other can be summarized as: Context is an interaction between “person, activity and place in space and time” and it has an influence on soundscape by three of other main concepts; auditory sensation, interpretation of auditory sensations/auditory perception and responses. Besides, these three concepts are influenced by different factors like personal and cultural characteristics, expectation, attitude, past experiences, activities, mood, temporal situations, lighting and thermal conditions (3).

ISO standard which highlighted many factors and interactions between them can be a useful guide for urban soundscape design, but it is not sufficient for indoor soundscaping. There are other essential factors that are needed consideration, while studying on an enclosed soundscape; architectural characteristics and function of a space. Architectural features have a significant influence on formation of sound (7), and this may affect the soundscape perception, just as function of a space affects the expectation of users.

Another indispensable issue is describing and standardizing the data collection methods about relevant factors and data types. Regarding both urban and indoor soundscaping, it is crucial to insert methods and data types to standards besides the factors of soundscape, in order to prepare advanced guide for design process of soundscapes.

### **2.2 Factors of Indoor Soundscaping**

The most apparent characteristic of soundscape approach that differs it from noise management is multi-factorial context of soundscape research field, additional to acoustical measurements and other objective parameters that are included. Through the review of several studies in the literature (1, 3-8) and the guidance of ISO 12913-1:2014 (3), it is possible to specify the factors of indoor soundscape.

As the soundscape heavily depends on the perception of the acoustic environment, urban soundscape deals with acoustical variables and various contextual factors to identify the perception of users. However, urban soundscape factors are not solely sufficient to evaluate an enclosed soundscape. Therefore, differently from soundscape in urban scale, indoor soundscape factors can be classified into three main concepts as suggested in the Dökmeci and Kang’s model when the architectural dimensions have been integrated to acoustical and contextual factors (7). Another integrative model was presented in Herranz-Pascual, Aspuru and García’s study (8) which defines the user, activity and place interaction to explain “environmental experience”. Based on Herranz-Pascual, Aspuru and García’s model it can be said that, contextual factors answer the questions such as; ‘how people experience and perceive their built and acoustic environment?’, ‘what type of sensations they have?’, ‘how they evaluate them?’ and ‘what behavioral responses are obtained?’. When contextual factors are assessed in more detail, expectations which are mostly formed by the past experiences (6), and preference which differs according to the places, activities and functions (1) stands in the foreground, when compared to other dimensions. Furthermore, expectation has an influence on behavioral outcomes; therefore, expected soundscape is not always the same with preferred soundscape.

Architectural factors, which are specific to indoor soundscape framework can be assessed in three subgroups based on the studies in the literature (4, 7); function, architectural properties and physical

environment. While architectural properties of a space are important for its remarkable influence on formation of sound (7), function of a space is important due to the direct relation with expectation and preference of users.

A merged model for indoor soundscape factors, that can be seen in Figure 1, is prepared based on the related studies in the literature. Factors of indoor soundscape are assessed in three main concepts as, “acoustical variables”, “contextual factors” and “architectural factors” in the proposed model. Acoustical variables are needed in order to understand the physical properties of sound and used to compare findings with other soundscape studies, noise regulations and guidelines. Secondly, contextual factors can be assessed in four main elements as temporal data, psychological conditions, behavioral attitudes to soundscape and personal/demographical information of users. Thirdly, architectural factors, which have direct effect on soundscape are divided into three elements as; function, architectural properties and physical environment. Information on function of a space is important for design process of soundscape as it can help to collect possible future predictions on preference of users. Architectural properties of an indoor space affect user’s perception of soundscape through its influence on sound. Besides, psychological situations and soundscape perception of users may alter in different physical environmental conditions and as a result, overall space experience can form differently.

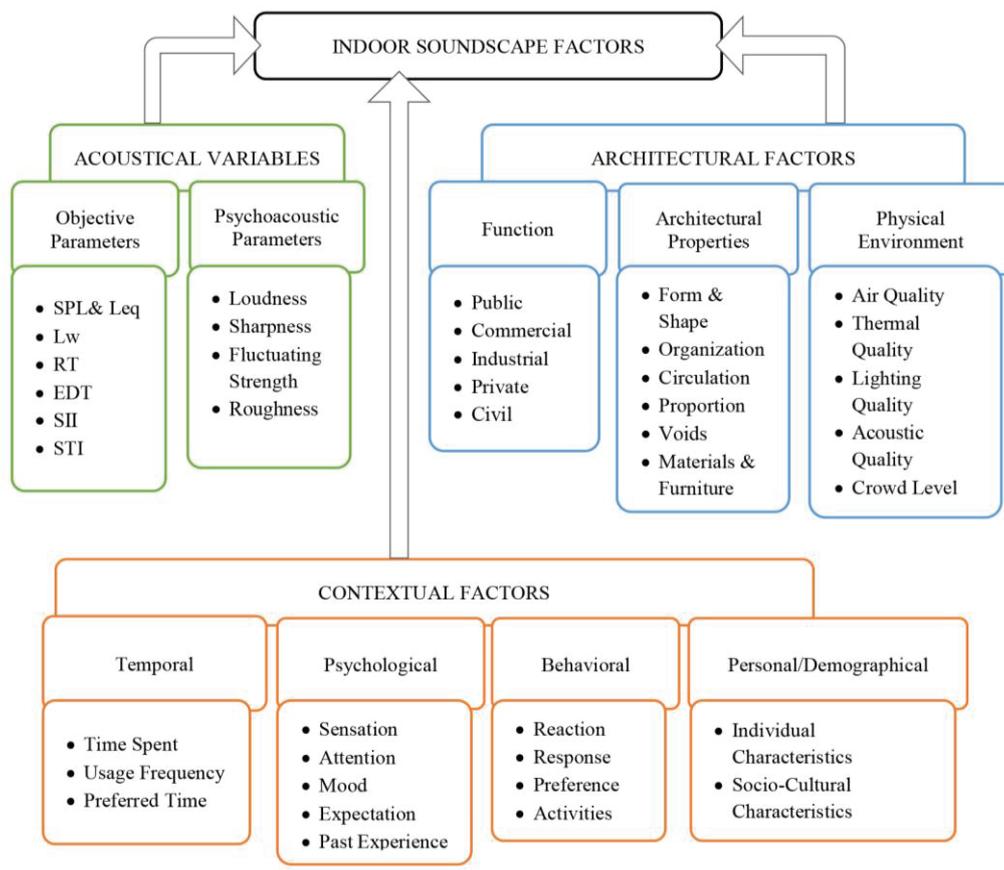


Figure 1 – Merged classification model for indoor soundscape factors (1, 3-8)

This model on soundscape factors is a classification proposal for indoor soundscaping factors, which needs further consideration in the process of architectural design by architects, interior architects or any other related discipline. Through further studies, it can be extended and/or evolved.

### 2.3 Methods of Indoor Soundscaping

Integration of soundscaping to the architectural design process especially in the early stages is crucial (4). Standardization and clarification of methods and data types, which are obtained from related factors, should be the subsequent step after factor identification, in order to integrate soundscape as a part of architectural design. Several urban soundscape studies related with the data types and methods in the literature divide methods as; in situ and laboratory studies (9, 11), and presents it as audience experience originated (10). Another study on indoor soundscape classifies methods for acoustical post-occupancy evaluation in three stages as “indicative” and “investigative”

as the identification phase of soundscape and “diagnostic” as the evaluative phase of soundscape (4). Under the scope of standardization and/or regulation establishment, it can also be useful to classify methods, based on the factors of indoor soundscape in order to evaluate factors and methods together. Classification of indoor soundscape methods, that can be seen in Table 1, is prepared based on the factors proposed in Figure 1. In Table 1, main 3 concepts of indoor soundscape factors and their methods for gathering data, types of data and finally the expected outcome that are planned to be obtained through those methods are presented.

Table 1 – A proposal on indoor soundscaping methods based on related factors (4, 9-11)

<b>Factor</b>	<b>Method</b>	<b>Data Type</b>	<b>Expected Outcome</b>
<b>Acoustical Variables</b>	Measurement	Quantitative	Physical properties of sound
<b>Contextual Factors</b>	Interview	Qualitative	How users perceive the soundscape in context
	Observation	Qualitative	
	Soundwalk	Qualitative	
	Questionnaire	Quantitative	
<b>Architectural Factors</b>	Architectural Survey	Quantitative	Architectural properties and information about physical environment

### 3. NOISE MANAGEMENT AND ITS APPLICATION

As a result of the policies that have been implemented in Turkey and EU, related regulations/directives and guidelines regarding noise management were published based on ISO acoustics standards.

#### 3.1 Noise Regulations/Directives in EU and Turkey

When the present noise regulations/directives of EU and Turkey were assessed, it is revealed that there are six essential regulations related to noise management. Table 2 presents a comparison of regulations in Turkey and EU, in terms of the scope and rule numbers. In table 2, it can be also seen that, four of the six regulations in Turkey have been prepared by reference from the equivalent directives in EU. These equivalent directives are about environmental noise management (12, 13), protection of the workers from risks of the noise exposure (14, 15), noise emission of outdoor equipment (16, 17) and sound levels of motor vehicles (18, 19). Besides, in Turkey, there is a regulation on, “protection of buildings against noise” (20) but an equivalent directive in EU does not exist. Furthermore, EU has a directive on noise-related operating restrictions at airports (21), which is not published in Turkey as an equivalent directive.

Table 2 – Comparison of noise regulations in Turkey and Europe.

<b>Scope of Regulation</b>	<b>Turkey</b>	<b>European Union</b>
1.Environmental noise	14012 (12) Amending 2002/49/EC	Directive 2002/49/EC (13)
2.Protection of buildings	23616 (20)	-
3.Protection of Workers	18647 (14) Reference 2003/10/EC	Directive 2003/10/EC (15)
4.Airports	-	Directive (EU) 598/2014 (21) Repealing 2002/30/EC
5.Outdoor equipment	2000/14/AT (16) Reference 2005/88/EC Reference 2000/14/EC	Directive 2005/88/EC (17) Amending 2000/14/EC
6.Motor vehicles	70/157/AT (18) Reference 2005/88/EC Reference 2000/14/EC	Regulation (EU) 540/2014 (19) Amending 2007/46/EC Repealing 70/150/EEC

When these regulations are compared and assessed, it can be said that there is not a remarkable difference between Turkey and EU, in fact, there is a compatible process about noise management. However, regulations on noise cannot be sufficient for soundscape standardization by itself, yet they need consideration, since noise management is a part of soundscaping.

### 3.2 Noise Guidelines in EU and Turkey

The essential aim of guidelines related to noise are; “to provide recommendations for protecting human health from exposure to environmental noise” (22) and to support implementation of environmental noise directive (23). In Europe, World Health Organization (WHO) prepared a series of guidelines about environmental noise and adverse health effects of the noise exposure for European region. On the other hand, the guidelines in Turkey were prepared under the scope of the twinning project TR/2004/IB/EN/02 “Harmonization and Implementation of the EU Directive Related to Environmental Noise Management”, which is promoted by European Commission (EC). Table 3 presents a list of these guidelines regarding environmental noise both in Turkey and Europe.

Table 3 – List of noise guidelines in Turkey and Europe

Turkey	Europe – World Health Organization (WHO)
1.Guideline on environmental noise measurement and evaluation (24)	1.Environmental noise guidelines for the European Region (22)
2.Guideline of noise reduction precautions (23)	2.Guidelines for community noise (25)
3.Noise mapping guideline (26)	3.Night noise guidelines for Europe (27)
	4.Methodology for systematic evidence reviews for the who noise guidelines for European region (28)
	5.Biological mechanisms related to cardiovascular and metabolic effects by environmental noise (29)
	6.Burden of disease from environmental noise (30)
	7.Results from the search for available systematic reviews and meta-analyses on environmental noise (31)

Guidelines in Turkey, which are about environmental noise measurement and evaluation (24), noise reduction precautions (23) and noise mapping (26), are not direct references of WHO’s guidelines, as it can be seen in the regulations. Nevertheless, contents are similar with WHO’s guidelines since they were prepared under the twinning project. When the European noise guidelines are evaluated a developing process can be seen clearly. The prior environmental noise guidelines of WHO are; Guidelines for Community Noise (25) which is published in 1999, was more-expert base and included more detailed technical issues on sound measurements and sources, and Night Noise Guideline (27) which was published in 2009, is related with the night noise exposure, sleep disturbance and night noise levels. The subsequent enhanced environmental noise guidelines of WHO (22, 28-31) were published including broader health outcomes of noise exposure, management of indoor noise levels and management of noise policies and regulatory standards (22). When the European and Turkish guidelines are compared it can be seen that Turkish guidelines are more similar with prior WHO’s guideline and they have deficiencies on health outcomes.

### 3.3 Standards (ISO-TS)

More than fifty standards in total are present in the literature, which are published under the name; “ISO/TC 43 Acoustics” by the technical committee and includes items such as, recommended sound levels, acoustical measurement protocols, evaluation and rating scales that are being used in noise directives and guidelines. Turkish Standard Institution (TSE) translated almost all of these standards, which have been used in the directives, into Turkish language. These translated Turkish standards (TS) have been used in the Turkish regulations and guidelines. Regarding soundscape regulatory attitude, present standards on acoustics will be essential as well to use standardized sound levels, measurement

techniques and data collection methods. The conspicuous standards that can be used in indoor soundscape framework are ISO 1996-1:1998 (TS equivalent: TS 9315 ISO 1996-1) (32) and ISO 1996-2:1987 (TS equivalent: TS ISO 1996-2) (33) which are related to environmental noise measurement, evaluations and sound levels. Standards, which are published by the Building Acoustics technical committee (ISO/TC43/SC 2) and standards of Noise technical committee (ISO/TC43/SC 1) may also need consideration for indoor soundscape regulatory approach.

#### **4. HOW TO IMPROVE INDOOR SOUNDSCAPE APPLICATION PROCESS?**

Soundscape has many factors influencing experience and perception of users in comparison with noise level. In other words, noise is not the only indicator that effects people in an acoustic environment. However, soundscape study field, that concerns all sounds, including positive and negative, have an influence on the experience and perception of users in an enclosed acoustic environment. The difficulty of researching in the soundscape field is to separately handle various factors as well as considering their interactions (10), since it is a rather subjective concept (4).

Therefore, to enhance the indoor soundscape quality and pleasantness, its integration to the architectural design process in early stages is crucial. However, the subjective attribution of soundscape arouses the necessity of characterizing the factors and methods, which are needed to be used in the design process. Certainly, a possible regulation/directive will also promote the integration of indoor soundscape principles to the design process. In that stage, evaluation of present policies on noise management has high importance on the process of developing a soundscape directive. When the present regulations/directives and guidelines are assessed, it is clearly seen that they have been prepared based on the standards published by the relevant institutions (e.g. ISO, TS). In addition, since soundscape approach involves noise management, noise policies and the related published documents should be in interaction with soundscape regulatory attitude. Therefore, preparation of standards regarding indoor soundscape factors and methods, which will be in cooperation with other acoustics standards in a possible regulation, can be the first stage. Simultaneously, the support and consultation of experts such as architects, acousticians, interior architects, related governmental institutions or ministries or any other related discipline would be beneficial for the standardization process of indoor soundscaping.

Secondly, since indoor soundscape expectation and preference differs regarding functional properties of a space, each case should be evaluated within itself. As it can be seen in the regulation on the Protection of Buildings Against Noise (20), soundscape evaluations in a possible future directive can be organized depending on the functional properties of enclosures. Hence, characterizing and separating the preference and expectation of users according to function and types of buildings may be needed, while preparing a standard that will be used in a future indoor soundscape regulation/directive.

Thirdly, a guideline on indoor soundscaping, which will inform public and related professions about soundscape factors, methods, effects and directive implementation, might be the last stage of enhancing indoor soundscaping that can lead it to be involved in the architectural design process.

In addition, with in the presented comparisons of noise and soundscape policies in this study, it can be seen that noise management developments in Turkey have been proceeded in cooperation substantially with EU policies. However, same attitude cannot be seen for soundscape approach. To develop a soundscape policy in Turkey, starting with the translation of ISO 12913-1:2014 (3) as an equivalent soundscape standard, and then starting to the improvement process is crucial.

#### **5. CONCLUSIONS**

Quality of indoor acoustic environment is one of the most essential issues to improve users' wellbeing since people spend most of their time in enclosed environments. Certainly, managing noise has great importance, but noise is not the only source that people are exposed to in an acoustic environment. Therefore, soundscape approach that includes noise management as well, is a better attitude to manage the whole acoustic environment, as it has extensive multi-factorial scope i.e. not limited with acoustical measurements but considers the human perception and context.

In this study, improvement of soundscape design process in terms of standardization and preparation of regulations were discussed. Since it is important to evaluate present policies on noise management and soundscape approach to discuss a possible regulation formation on indoor soundscape, standards, regulations/directives and guidelines in Turkey and EU were assessed in a comparative way. When these documents are analyzed it is seen that there is a gap on indoor

soundscaping regarding management, policy implementation, guideline preparation and standardization. The first step in the process of publishing a directive/guideline would be starting an initiative on preparation of a standard on factors and methods of indoor soundscaping. Thus, it can be possible to study on a directive specific to indoor soundscape in the later phase. In addition, guidelines should also be prepared in order to present an extensive informative document on indoor soundscape approach that can be followed in the architectural design process.

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