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Orginal Article

Effects of the environmental factors in call centre interiors: a case study

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Abstract: Environmental factors in workspaces affect employee productivity and satisfaction, particularly in call centres. One of the most challenging issues in contemporary offices is overcoming the problems of concentration on work, despite adverse effects such as insufficient lighting, inappropriate acoustics, or inadequate ventilation. The challenges increase in open-plan solutions. This paper presents a case study from Turkey that elaborates on strategies to improve environmental performance in call centres. It is inspired by a questionnaire conducted among employees of a call centre, identifying existing design lacks. Based on the results, acoustic quality calculations of the physical workspace follow, and initial computing outcomes reveal that the conditions do not meet the standards for call centres. The authors propose strategies to improve acoustic performance in the workspace and apply them to a virtual model. Results reveal that the proposed solutions allow for meeting the standards. Based on the findings, the authors suggest several other strategies for improving the physical environmental quality of the place, thus forming a guideline for the architectural design of call centres. The study derives information from a specific case and context to propose universally applicable solutions. It fills a gap in the literature as it exemplifies the characteristics of call centres in Turkey, which have not been studied before.

Keywords: open plan, open office, environmental factors, acoustic room comfort, architectural acoustics, physical workplace, healthy architecture, workspace

1. Introduction

The design of workspaces' physical environments is a research field with increasing interest. Spatial form and arrangement affect employee satisfaction and productivity, issues crucial for disciplines like marketing, finance, or management, as well as architecture and design. For architects, planning workspaces is related to creating healthy and sustainable environments that contribute positively to the short- and long-term physical, mental, and psychological health of users. Many researchers from various fields of architecture and design have studied the quality of the physical environment in workspaces from different perspectives (yet, in practice, various malfunctioning cases are observed). In general, the physical quality of the workspace is defined through a possibility-driven, balanced approach, fitting the users and effectively enhancing the environment for the long term [1]. The issue is critical as employees mostly spend one-third to 90% of their days at work [2]. The concern addresses not only matters of health but also the success and sense of belonging of the employees to their companies. Existing literature shows that high-quality physical environments contribute to productivity [2–6]. The main issues regarding the health and quality of workspaces are outlined by studies [7–9] and official regulations [11], [12]. Some of the criteria that define the quality of the physical environment in a workspace are light quality, air quality, furniture and layout quality, and acoustic quality.

This paper is based on a questionnaire about the qualities of the physical environment and concerns the employees of a call centre. Considering office spaces, particularly call centres throughout the world, the open office is still the main layout [12]. Therefore, there is still a need for improvement in the quality of these workspaces, so that every research provides an important contribution to the subject. Additionally, the fact that there are not enough studies in the literature about office spaces or call centre interiors in Turkey makes this article a significant contribution to the field. The questionnaire showed that acoustic quality is the most important criterion affecting the quality of the physical environment. Therefore, the following chapters of the article mainly elaborate on the theoretical framework of the potential effects of acoustics on workspace quality. This consideration follows with strategies applicable in a call centre workspace to increase sound field comfort.

This study contributes to the discussion, showing possible development paths and increasing social awareness of the role of good working conditions, both for the activities of employees and employers.

1.1. Problem outline

Transparency and connectivity are two main focal points of contemporary office design [13]. Employees' concentration on their work is one of the most challenging issues, as they are often distracted by background noise and the speech of peers. Therefore, acoustic quality is crucial to the success of workspace design. However, it is often judged as one of the least satisfactory aspects of office spaces. Attention to a sound environment may ensure a higher quality in the overall experience of workspaces, concerning:

- low noise levels,
- speech privacy,
- productivity [14], [15].

Especially in open-plan offices, acoustic solutions have a crucial impact on the productivity and satisfaction of employees [14], [16].

The open office plan is a popular design scheme because it provides an organized, visible interior with fast employee communication. The call centre is a type of workspace where most tasks are completed on the phone and PC, based on verbal conversations [17]. The circulation of documents is simple and direct, and managers have a good overview of task implementation [18]. A call centre's productivity and success originate from the performance of its employees. Thus, their satisfaction is significant. The employees must not be distracted by others' conversations, and the background noise should not exceed the reference of equivalent sound level for the internal sound equivalent to the external noise A-correction curve of 40 dB [19].

1.2. Definitions

Several acoustic parameters determine the sound field, which can be comfortable or unfavourable to the user. They are as listed:

- Equivalent sound level (LAeq) is a quantity used to describe a sound that varies in time. It equals the averaged energy of the sound level, determined for a given observation time and corrected by the hearing curve A [20].
- "The reverberation time T60 is defined as the time in seconds, necessary for an impulsive or interrupted test sound to drop by 60dB compared to its maximum level, reduced by 5dB." [21].
- The Speech Transmission Index (STI) is a parameter that shows speech intelligibility. It relates to clarity, lateral energy fraction, and interaural cross-correlation coefficients. It ranges between values 0 and 1, where 0 means poor and 1 means excellent [20].

We define acoustic comfort in the open office following standards: PN-B-02151-4 [22], PN-B-02151-3 [19], where:

- Permitted equivalent sound level (LAeq) LAeq $\leq$ 40dB
- Reverberation time (RT) $\leq$ 0.6s

The STI is a complex parameter and requires measurements or advanced computing. Thus, for these theoretical considerations, we assume that if the acoustic absorbance (A) of the room is efficient (meets $A \geq 1.1S$, where S is the surface of the room in m^2).

1.3. Methodology

The general methodology of the study consists of a review to determine the existing state of the academic literature, followed by a survey as the Post-Occupancy Evaluation (POE) quantitative research method to describe the opinions of users in the given workspace as the sample population [23–25], and finalized with several architectural proposals to increase the quality of the physical environment. The study comprises a few parts. Therefore, the detailed methods are described accordingly with each piece of information. The POE method, elaborated by Preiser, Rabinowitz, and White in 1988, consists of several main steps. In the research, we focused on two procedures: indicative – a general evaluation of issues that require further investigation, and investigative – Evidence-Based Design (EBD) concerning re-design matters aiming at raising, among others, spatial and functional quality [24, 25]. Architectural proposals come from the outcomes derived from the survey results. The design work on a virtual model of the workspace prepared using CAD software served the acoustic qualities analysis. Thanks to the virtual model, it was possible to validate the outcomes of the proposed strategies for their contribution.

The questionnaire was conducted in a call centre in Istanbul, Turkey. This research continues the previous one, prepared to evaluate the overall relationship of the employees with their physical environment in the workspace. Questions focused on the quality of the physical environment and the performance of the workspace. The authors, in collaboration with the managers of the call centre and external consultants, prepared the questionnaire based on previous experience and observations. The managers checked all questions prepared by the authors for suitability to the company principles and workflow and approved them. Then the questionnaire was published in the Google Forms format to be easily accessible by the participants at any time and place. Participants were recruited among the call centre agents of the same company, who shared the same workspace in the same building. There was no obligation to participate, so only willing agents participated. In total, 521 employees participated in the questionnaire, sharing their thoughts and opinions. Considering the total number of employees, which is 1,346, the participants of the questionnaire constitute 38.7% of the total. Therefore, this ratio can be considered representative of the whole population.

The questionnaire consisted of three main sections. The first section aimed to analyse the employee profile with their demographic information, the second section aimed to question their opinions about the physical environment in which they work, and the third section asked the participants for their comments. Appendix A presents a copy of the questionnaire in Turkish and English. The subsequent chapters of the paper elaborate on the answers received from the call centre employees, particularly on the quantitative results of the second section.

The authors needed to respect the confidentiality of the host corporation and the personal data of its employees. Therefore, the basis for the study is a theoretical, virtual, and three-dimensional room model. It reflects the original architectural geometry and aligns with the materials used in the workspace. The authors performed the reverberation time (RT) and acoustic room absorbance (A) calculations following formula 1 from the Polish Standard PN-B-02151-4 [22], which is specifically addressed to open-plan offices – point 4.2.3, table position 1. The equation (1) is:

$$A = \sum_{i=1}^{n} \alpha_i S_i + \sum_{j=1}^{o} A_{V,j} + A_{air} \tag{1}$$

where: n – the number of surfaces i, o – number of objects j, α_i – absorbing coefficient of surfaces i, S_i – surfaces area i, in [m^2], $A_{v,j}$ – acoustic absorption of singular object j, in [m^2], A_{air} – acoustic absorption in [m^2] of air absorption j, in [m^2], determined by the formula:

$$A_{air} = 4mV \tag{2}$$

where: m – power sound absorption coefficient in the air in [Np/m], N_p – Neper, V – Room volume in [m^3],

The reverberation time (RT) is calculated based on norm Polish Standard PN-B-02151-3_2015-10P [19], according to the following formula:

$$RT = 0.16\frac{V}{A} \tag{3}$$

where: A is a parameter of acoustic room absorbance for a medium frequency of 500Hz, calculated for an empty room.

After initial calculations, the open office was redesigned, focusing on adding sound-absorbing quality and shortening the reverberation time. A second round of computing was applied according to the same formulas. A comparative analysis of results from both outcomes served to formulate conclusions.

2. Criteria for physical quality in workspaces

The physical qualities of workspaces play a significant role in employees' well-being, productivity, and satisfaction. The environment can affect both the physical and mental aspects of employees. The most important factors are acoustics, furniture and layout, air quality, and lighting. This chapter discusses the importance of these factors in workspaces and their impact on employee well-being and productivity.

2.1. Lighting

Lighting is a crucial physical quality criterion that affects employee performance, mood, and health. Inadequate lighting can lead to eye strain, headaches, and fatigue, among other health problems. On the other hand, proper lighting can enhance employee mood, productivity, and alertness. According to Narendran et al. [26], lighting design in workspaces should consider the type and amount of light required for tasks performed in the workplace. Lighting should also be adjustable to cater to individual preferences and tasks. Natural light is crucial as it can enhance employee mood and productivity and reduce the risk of depression. A recent study [27] shows that lighting can affect employee circadian rhythm and sleep quality. The study suggests that exposure to natural light during the workday can improve sleep quality and enhance employee well-being.

2.2. Air quality

Air quality is also crucial in workspaces as it affects employee health, comfort, and productivity. Poor air quality can cause respiratory issues, allergies, fatigue, and other health problems for employees. Indoor air pollutants such as volatile organic compounds (VOCs), carbon dioxide (CO_2), and dust particles can lead to sick building syndrome (SBS), a condition where employees experience a range of symptoms, including headaches, eye irritation, and respiratory problems, among others. According to Geng et al. [28], poor indoor air quality can affect employees' cognitive functions and reduce productivity. Improved air quality can enhance human cognitive performance, leading to better work outcomes. Additionally, improved air quality reduces absenteeism and saves costs for organizations. Therefore, institutional management should prioritize air quality by ensuring proper natural ventilation, air filtration, and maintenance of HVAC systems.

2.3. Furniture and layout

Furniture and layout are crucial physical qualities that impact employee well-being and productivity [29]. The right furniture and layout design can enhance employee comfort, satisfaction, and productivity. Ergonomic furniture design can reduce musculoskeletal disorders and improve employee comfort and productivity [30]. Additionally, furniture should be adjustable to cater to individual preferences and tasks. Zhang et al. [31] suggest that the workspace layout should consider the type of work performed in the space. For instance, spaces requiring collaboration, such as open offices, should have a layout that promotes interaction and teamwork. However, work based on personal performance, as seen in call centres, also requires isolation from each other, using furniture elements like partitions for better concentration.

2.4. Acoustics

Acoustics play a significant role in employee well-being and productivity in workspaces. Excessive noise levels in the workspace can cause hearing loss, stress, and reduced productivity. On the other hand, the right sound quality can enhance employee concentration and performance. Sound-absorbing materials in workspaces can reduce noise levels and improve employee well-being and productivity [32]. Additionally, sound masking techniques, such as white noise, can help to improve speech privacy and reduce noise distractions. Candido et al. [33] suggest that workspace design should consider the type of work performed in the space. For instance, spaces that require concentration, such as offices and meeting rooms, should have low noise levels to enhance employee focus and productivity.

Even though there is much research in the academic literature [31], [34–38] studying the impact of noise levels, sound quality, and sound-absorbing materials on call centre employees' speech recognition, cognitive performance, and job satisfaction, in professional life the issue of acoustic quality in call centres is still neglected. Nowadays, around 20% of Europeans experience long-term road noise negatively affecting their health [40]. Noise is harmful in various aspects in both short- and long-term exposure. Problems go far beyond hearing damage. From the hearing aspect, threshold rise to permanent loss, tinnitus, or hyperacusis may occur. Excessive sound affects sleep, and the nervous system, harms the cardiovascular and metabolic systems, and may also cause cognitive impairment, especially in children [40–41]. As a European Union expert Peris [39, p.2] indicates, noise causes 12,000 premature deaths yearly. It also lowers well-being when around 22 million Europeans suffer from chronic irritation. Office workers complain about a lack of concentration caused by noise exposure. Additionally, acoustic issues revealed problems with stress, depression, overall health, and more accidents. Analysis of this data proves that every step taken toward noise limitation is valid and desirable. Considering health issues caused by noise, acoustic comfort is a crucial element of the office workspace. It favours concentration, work safety, good peer-to-peer and client communication, effectiveness, and overall human well-being [14], [42], [43].

3. Initial data

The first section of the questionnaire [44] consisted of several multiple-choice questions about the age, gender, and experience level of the employees. The gender question revealed that 61.2% of the participants were male and 29.4% were female. The question about age showed that the majority, 60.8% of the participants, were between 25 and 28 years old. 29.4% were between 29 and 32, and 7.9% were between 21 and 24 years. The question about the length of their work experience in the call centre indicated that 36.7% of the participants had worked there for only 1 year. 23.5% had worked there for 2-3 years, 20.4% for 3-5 years, and 17.3% for 1-2 years in that call centre. The question about smoking status revealed that 58.6% were non-smokers and 41.4% of the participants were smokers. Lastly, the question about transportation choices revealed that the majority of the agents, 93.4%, were using the transportation services of the employer. Only 5.4% of the participants said they use their private vehicles to commute between work and home. Figure 1 illustrates the results for the first section of the questionnaire:

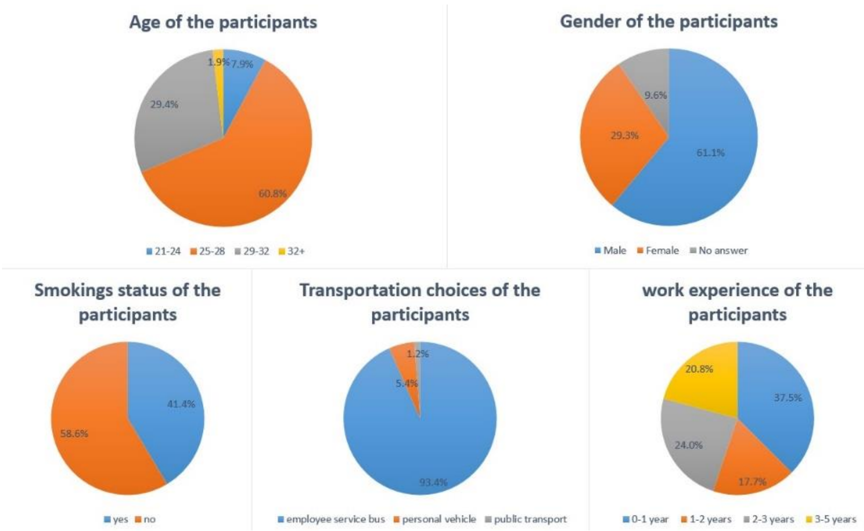

Fig. 1. Results for the first section of the questionnaire. *Source*: own study

3.1. Questionnaire results

The second section of the questionnaire included participants' opinions about their workspace's physical environment and spatial layout. A total of twelve questions were posed, and a 5-point Likert scale was used for evaluation. The Likert scale follows Jamieson's [45] definition: "A Likert scale [...] is designed to measure people's attitudes, opinions, or perceptions. [...] responses typically include 'strongly agree,' 'agree,' 'neutral,' 'disagree,' and 'strongly disagree.' Often, the response categories are coded numerically, so the numerical values must be defined for that specific study, such as 1 = strongly agree, 2 = agree, and so on."

The overall average value for all responses from each participant was 3.162, which served as the base point for assessing each question result (Table 1).

Table 1. Results for the second section of the questionnaire *Source:* own study

Subject	Mean value
external acoustic insulation	2.719
interior air quality	2.994
natural ventilation	3.138
artificial air conditioning	3.101
interior acoustic quality	2.825
sufficiency of natural lighting	3.448
sufficiency of artificial lighting	3.667
distance between workstations	3.048
circulation areas	3.515
personalization opportunities	2.838
personal space	3.023
quality of materials and furniture	3.635

The results indicate that the highest evaluations for the physical environment and layout concerned artificial lighting, natural lighting, and the quality of materials and furniture. Additionally, circulation opportunities were mainly evaluated positively. However, participants' opinions about the personal space in the office and some environmental quality elements were relatively negative. The lowest result for evaluating the physical environment concerned the interior acoustic quality and the sound insulation from exterior sources. The mean value for interior acoustic quality was 2.825, and the mean value for acoustic insulation from exterior sources was 2.719. The other points that were evaluated negatively by the employees were personal space and personalization opportunities. Additionally, even though they did not result as low as the acoustic issues, interior air quality and acclimatization issues were also considered weak points of the physical environment in the call centre workspace.

3.2. Solution possibilities

The questionnaire results highlighted three different aspects of environmental factors in the call centre. The first aspect is based on acoustic issues, the second originates from the layout, and the third concerns indoor air quality. The following chapters will primarily elaborate on acoustics as the most significant result of the questionnaire, but issues regarding layout and air conditioning will also be mentioned.

Based on the questionnaire results, we assert that one of the most crucial problems in the physical environment of the call centre has been acoustics. Improvement of the overall quality of the physical environment in the call centre workspace requires strategies to improve the acoustic quality in the given area. It was proven that the noise comes from all four sources stated in the literature [17]. They are as listed:

- human activity,
- office equipment,
- building indoor installations,
- outdoor noise.

Lee and Aletta [46] focus on four main strategies to improve acoustic comfort in a workspace: space planning measures, including zoning; technical measures and materials; construction methods and elements with details to provide sound insulation; and occupant control of noise. However, introducing such a complex approach requires planning a project from scratch. For existing solutions, rearranging the architectural layout or changing appliances into quieter ones may be too complicated and expensive. For the case study within the scope of this paper, the authors had to focus on increasing the acoustic quality of the interior space, even though the questionnaire results indicated that external acoustic insulation was a more significant problem for employees. There are two reasons for this decision. Firstly, applying strategies to improve acoustic performance in the interior space is much easier. Secondly, the location of the building near a busy highway makes the situation insoluble except for redesigning the whole building envelope, which is a significant operation. One of the strategies to improve acoustic performance in a call centre is to design a furniture system with sound-absorbing materials, as proposed by Geniola et al. [47]. Roelofsen [48] shows that in particular cases, a conversation may be more disruptive for the concentration process than regular background noise. Thus, its direct muting may be beneficial to the employees on nearby workstations. The second strategy, as stated by Peris [39], is adding green spaces. The soft ground that comes with such areas is a natural absorbing material for excessive acoustic energy. Such a solution applies to both the exterior and interior.

3.3. Initial sound field parameters

Fortunately, the proper values of RT, A, and STI allow for limiting inner noise regardless of its source. Firstly, we modelled the studied office in a three-dimensional virtual space, applying existing materials to the room. Secondly, we calculated RT and A for base frequencies as listed: 125 Hz, 250 Hz, 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz. Thirdly, we redesigned the office with new, acoustically absorbing materials and performed the next round of calculations. The researched office has an elongated open plan of rectangular shape (8.45x49.5 m) with two shallow "pockets" (2.9x7.87 m and 6.6x14.55 m) and a height of 2.35 m to the suspended ceiling and 2.18m to the structure. The total surface equals 256 m², and the volume is 1250.35 m³. The walls are smooth, plastered, and painted, with a strip of large windows on one of the long sides. On the opposite wall, there are doors and file cabinets. One of the shorter walls is fully glazed, and the other has a strip of windows. The room is carpeted, and parts of the ceiling have minor absorbing qualities. Evenly spaced desks grouped in three or six workstations are divided with Plexiglas partitions (Fig. 2).

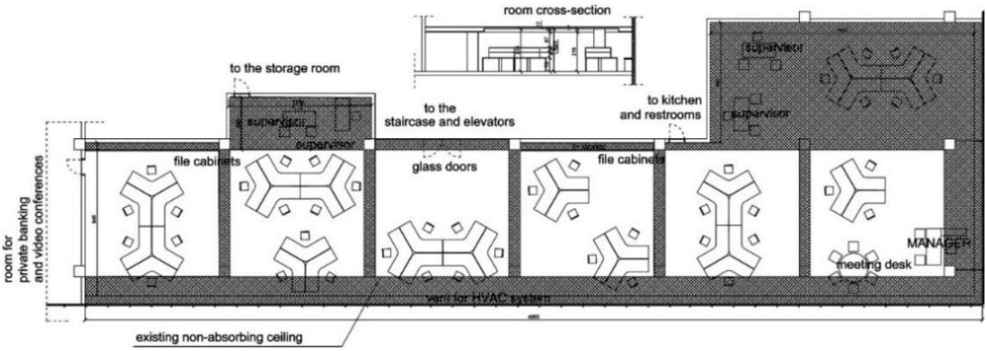

Fig. 2. The examined room layout and cross-section – existing state *Source:* own elaboration

According to the standard PN-B-02151-4 [22], the room's absorption must be equal to or exceed 1.1xS, where S denotes the room surface. Thus, the A of the room needs to exceed 578 m². Therefore, we first calculated the existing absorbing performance of the room according to formula no. 1. The next condition outlined by the standard is that the space must follow the parameter when it is empty. Thus, firstly, we calculated the existing absorbing performance of the room for the model of a room without furniture. Secondly, we divided the whole room into elements using acoustically relevant materials. For each extracted part, the surface area was calculated. Finally, we assigned their absorbing coefficients depending on the frequency and computed the total A [m²] for each element (Table 2).

Table 2. Acoustic absorbance of room elements – Input data and calculation for the initial state *Source:* own elaboration

Description			A_i						
The room element	S_i	Material	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	125 Hz
Floor	256	carpeting (6 mm on foam film)	7.68	23.04	64	79.36	84.48	112.64	7.68
Sidewall (left)	18.6	absorbing wall panel	11.16	17.67	18.6	18.6	18.6	18.6	11.16
Sidewall (left) – door	1.89	wood	0.2646	0.189	0.1512	0.1512	0.1512	0.1512	0.2646
Front wall	36	absorbing wall panel	21.6	34.2	36	36	36	36	21.6
Front wall – windows	107	glass	10.7	7.49	5.35	3.21	2.14	2.14	10.7
Sidewall (right) – windows	33.8	glass	3.38	2.366	1.69	1.014	0.676	0.676	3.38
Sidewall (right)	11.3	absorbing wall panel	6.78	10.735	11.3	11.3	11.3	11.3	6.78
Back wall (absorbing)	100.9	absorbing wall panel	60.54	95.855	100.9	100.9	100.9	100.9	60.54
Back wall (non-absorbing)	65.1	plaster	1.302	1.302	1.953	2.604	3.255	3.255	1.302
Back wall – door	1.89	wood	0.2646	0.189	0.1512	0.1512	0.1512	0.1512	0.2646
Pillars	43.24	absorbing wall panel	25.944	41.078	43.24	43.24	43.24	43.24	25.944
Back wall – glazed	22	double glass	2.2	1.54	1.1	0.66	0.44	0.44	2.2
New absorbing walls	26.79	2xabsorbing wall panel	2.679	1.8753	1.3395	0.8037	0.5358	0.5358	2.679
Ceiling – absorbing	306	absorbing ceiling*	183.6	290.7	306	306	306	306	183.6
Ceiling – absorbing (changed)	248.2	absorbing wall panel	148.92	235.79	248.2	248.2	248.2	248.2	148.92
The sum			487.0142	764.0193	839.9749	852.1941	856.0692	884.2292	487.0142

Afterwards, we computed the air absorbing quality in the given room – according to formula no. 2 (Table 3).

Table 3. Acoustic absorbance of air in the room – input data and calculation for the initial state *Source:* own elaboration

		The power air sound absorption coefficient [Np/m]						The air in the room absorbance					
The room element	Vol.	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz
Air in the room**	1250.35	0.0001	0.0003	0.0006	0.001	0.0019	0.0058	0.50014	1.50042	3.00084	5.0014	9.50266	29.00812

** Air at 20°C and humidity between 20-50%

Adding values from Tables 1 and 2 allows for calculating the room's total acoustic absorbance. The juxtaposition of outcomes serves as comparative data toward the initial A value of the room (Table 4). For better visualization of the results, we used a graphical representation (Fig. 3).

Table 4. Total acoustic absorbance of the room – initial stage *Source:* own elaboration

	The room absorbance					
Frequency	125Hz	250Hz	500Hz	1 kHz	2 kHz	4 kHz
A [m2]	219.1	337.5	397.1	416.5	429.7	477.4
A [m2]	578	578	578	578	578	578

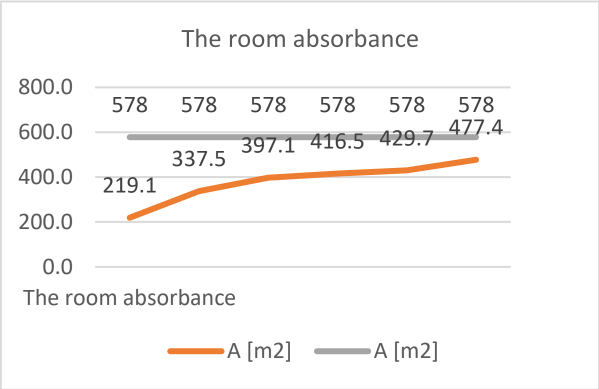

Fig. 3. Graph comparing computed data for acoustic absorbance of room A – computed with required value of absorbance *Source:* own elaboration

The RT – calculated according to formula no. 3 – equals 0.5031.98 s, which is significantly elongated according to the standard PN-B-02151-4 [22]. Summarizing this part of the investigation, we can conclude that the total acoustic absorbance of the room is insufficient.

4. The strategies

4.1. Acoustics

Thus, we investigated a scenario in which the room incorporates materials and solutions aiming more precisely at acoustic absorbance. Due to the relatively low room, we propose changing the existing non-absorbent ceiling filling into a more absorbent one in class A. A similar material or panelling may be applied to all unobscured parts of the walls – both sidewalls and the parapet front wall. The back wall holds the filing cabinets, but there is still space for acoustic improvement. We also propose covering the inner pillars with sound-absorbing material, thus providing a more balanced acoustic field (Fig. 4).

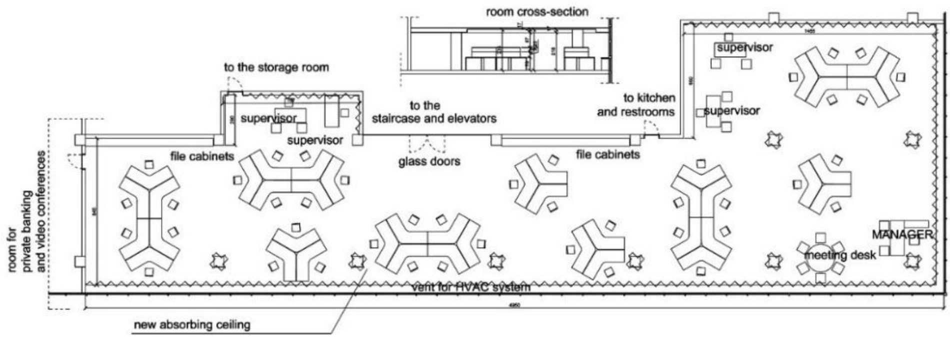

Fig. 4. The examined room layout and cross-section – the design state *Source:* own elaboration

The calculation outcome is presented below in the juxtaposition of Tables 5 and 6 and the graph in Fig. 5, which was done according to formulas 1–3. We assumed that air-absorbing qualities remain the same.

Table 5. Acoustic absorbance of room elements – input data and calculation for the design state *Source:* own elaboration

Description			A_i						
The room element	Si [m2]	The element's material	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	125 Hz
Floor	256	carpeting (6 mm on foam film)	7.68	23.04	64	79.36	84.48	112.64	7.68
Sidewall (left)	18.6	absorbing wall panel	11.16	17.67	18.6	18.6	18.6	18.6	11.16
Sidewall (left) – door	1.89	wood	0.2646	0.189	0.1512	0.1512	0.1512	0.1512	0.2646
Front wall	36	absorbing wall panel	21.6	34.2	36	36	36	36	21.6
Front wall – windows	107	glass	10.7	7.49	5.35	3.21	2.14	2.14	10.7
Sidewall (right) – windows	33.8	glass	3.38	2.366	1.69	1.014	0.676	0.676	3.38
Sidewall (right)	11.3	absorbing wall panel	6.78	10.735	11.3	11.3	11.3	11.3	6.78
Back wall (absorbing)	100.9	absorbing wall panel	60.54	95.855	100.9	100.9	100.9	100.9	60.54
Back wall (non-absorbing)	65.1	plaster	1.302	1.302	1.953	2.604	3.255	3.255	1.302
Back wall – door	1.89	wood	0.2646	0.189	0.1512	0.1512	0.1512	0.1512	0.2646
Pillars	43.24	absorbing wall panel	25.944	41.078	43.24	43.24	43.24	43.24	25.944
Back wall – glazed	22	double glass	2.2	1.54	1.1	0.66	0.44	0.44	2.2
New absorbing walls	26.79	2xabsorbing wall panel	2.679	1.8753	1.3395	0.8037	0.5358	0.5358	2.679
Ceiling – absorbing	306	absorbing ceiling *	183.6	290.7	306	306	306	306	183.6
Ceiling – absorbing (changed)	248.2	absorbing wall panel	148.92	235.79	248.2	248.2	248.2	248.2	148.92
The sum			487.0142	764.0193	839.9749	852.1941	856.0692	884.2292	487.0142

Table 6. Total acoustic absorbance of the room – design stage *Source:* own elaboration

	The room absorbance					
Frequency	125Hz	250Hz	500Hz	1 kHz	2 kHz	4 kHz
A [m2]	488.0	767.0	846.0	862.2	875.1	942.2
A [m2]	578	578	578	578	578	578

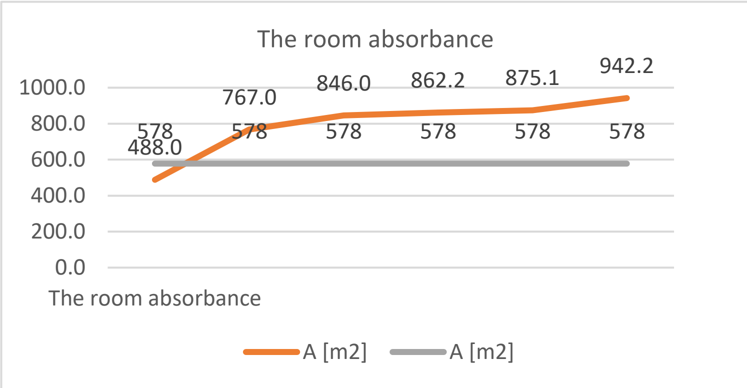

Fig. 5. The graphic with designed acoustic absorbance A – designed (empty room) *Source:* own elaboration

We also recommend changing the appliances and utilities to those with the lowest possible noise emissions, as provided by the producers in decibels [dB] in the product technical specifications. Employee comfort will also increase if the partition walls incorporate absorbent material along with transparent panels. This design will directly absorb the acoustic energy generated when employees talk on the phone. It also enhances privacy, which, as shown by De Been and Beijer [49], is a valid factor not only for improving worker comfort but also for boosting their efficiency. The proposed wall design is illustrated in the drawing below (Fig. 6). While introducing desk plants may seem like a small gesture, the soil in pots can absorb unwanted sounds [50]. Such solutions can maximize employee efficiency, helping them concentrate better and hear clients during phone conversations. Given that much noise originates from the external environment, even when windows and doors are closed, it becomes necessary to upgrade these elements to improve insulation [51]. The specific parameters for these changes should be the subject of additional calculations, which are beyond the scope of this study.

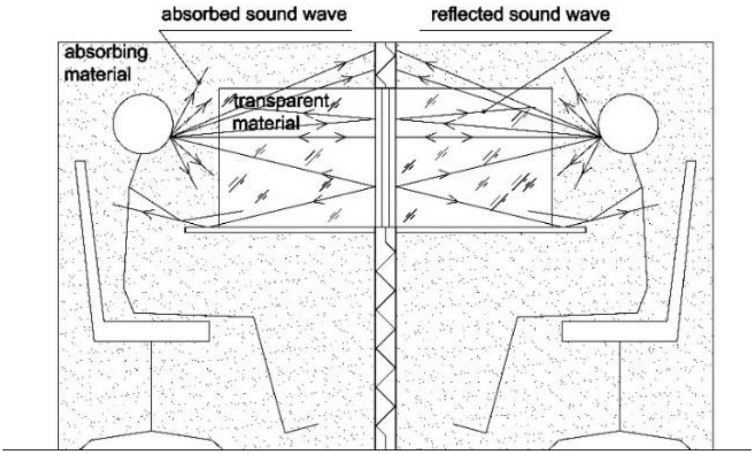

Fig. 6. The graphic illustrating the proposed desk separation wall with sound-absorbing properties. *Source:* own elaboration

The most significant results of the questionnaire pertained to acoustics, and the studies primarily focused on potential improvements in sound field performance. However, the questionnaire also yielded other findings, specifically concerning layout and interior air quality, which also required attention. The following subchapters of the paper provide a summary of the proposed improvements for these issues.

4.2. Furniture and layout

As the second most significant finding, the questionnaire revealed that call centre agents had a negative impression of issues related to space layout. Workspace design must be considered an aspect of ergonomics and comfort, directly impacting occupants' satisfaction [52]. Participants in the questionnaire expressed negative opinions about personal space, personalization options in workstations, and the distance between workstations (Fig. 1). Therefore, improvements are needed in areas such as personalizing the work area, providing space for collaboration, enhancing the comfort of furnishings, and ensuring an adequate amount of workspace [53]. Additionally, the workspace layout should strike a balance between visual privacy and collaboration. Excessive, uncontrolled social contact due to proximity can lead to overall negative reactions toward the office environment, as suggested by [54].

Therefore, the following strategies are proposed for better space organization within the given call centre interior (Fig. 7):

- achieve a more balanced use of space by optimizing empty areas and adjusting the distance between each workstation;
- allocate fixed or shared workstations for each agent based on their personal and professional relationships with one another;
- relocate spaces such as meeting rooms, storage, or technical rooms to create additional useful space for the primary function, thus increasing personal space for each agent;
- implement a more personalized and informal arrangement for resting and collaboration areas for agents;
- make more effective use of the areas near the windows, both to optimize space utilization and take advantage of natural daylight.

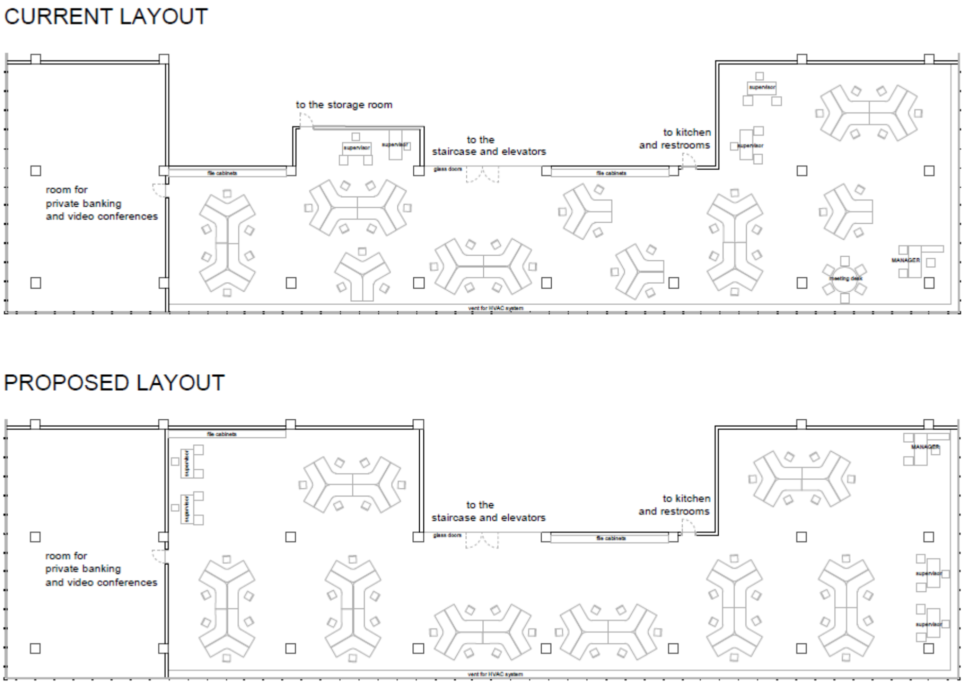

Fig. 7. Current and proposed layouts for the main utility area of the call centre *Source:* own elaboration

4.3. Indoor air quality

Indoor air quality has been the third aspect of environmental factors in the given call centre interior. This aspect and thermal comfort are two crucial elements of indoor environmental quality [55]. Achieving energy-efficient buildings and maintaining proper indoor environments [56], [57] are also critical. Titles related to air quality that received negative feedback from questionnaire participants include interior air quality, artificial air conditioning, and natural ventilation. Unfortunately, it was not possible to conduct any measurements for indoor air quality. Therefore, the recommendations are based on previous experience, statements from the questionnaire participants, and a literature review. We recommend improving the quality of indoor air as follows:

- avoiding extreme temperatures and strong drafts for both heating and cooling;
- providing an indirect flow of air from the vents instead of direct ventilation;
- diluting indoor contaminants by incorporating additional elements in ventilation systems [58];
- making more effective use of natural ventilation by actively utilizing spaces near windows (although this might have negative implications for acoustic quality).;
- using humidifying devices to enhance indoor air quality within the open office;
- implementing strict separation between the workspace and circulation areas, kitchens, and restrooms.

5. Conclusions

The presented study is based on questionnaire results conducted in a call centre in Istanbul, Turkey, in 2021, with a sample of 521 employees, one of whom is an author of this article. The study focused on assessing the quality of the physical environment and highlighted the critical importance of acoustics in workspace design. Respondents identified various shortcomings in interior sound fields, which were thoroughly investigated through calculations performed on a virtual 3D room model.

While call centres often prioritize technological solutions such as high-quality headphones and microphones, it is essential to address the overall acoustic quality of the workspace. To this end, we proposed strategies for physical spatial improvements aimed at enhancing sound absorption in the room. These design interventions involve modifications to existing building elements and the introduction of new acoustic materials in specific locations within the room. The planned changes were validated through a second round of calculations for Reverberation Time (RT) and Acoustic Absorbance (A). Additional solutions include the installation of desk partitions and the introduction of indoor plants.

Based on the findings and insights from this study, the following guidelines are recommended for open office plan call centres:

- each design case should be considered separately while taking into account the needs and expectations of both employees and employers;
- research on workers' opinions requires anonymization to gather objective data, especially in cases where a conflict of interest may arise;
- architectural acoustic strategies are necessary to provide sound field quality without compromising visual and functional connectivity and circulation requirements in the workspace;
- architectural acoustics should take precedence in workplace ergonomics before technological support, including the computation of Reverberation Time and Sound Absorption parameters;
- the choice of sound-absorbent materials and furniture for open offices is critical, considering parameters like RT and A;
- indoor greenery can be beneficial both for acoustic purposes (through ground or humus contained in pots and vertical systems) and psychological well-being;
- sound-absorbing curtains or partitions can help minimize the disruptive effects of exterior sources;
- the use of quiet office equipment and appliances is advisable;
- in the case of existing buildings, a costlier operation (if permitted) involves changing doors and windows to ones with better sound isolation or adding a second skin to the building's façade;
- to enhance indoor air quality, a harmonious combination of natural ventilation and artificial air conditioning systems should be employed;
- effective separation between workspaces and circulation areas, staircases, elevators, and supporting areas can enhance employee concentration and productivity;
- good building and architectural design contribute to increased employee efficiency and the company's overall income.

These guidelines help plan and design any open-plan call centre since they were established based on recalled literature and good practices in this field. The study also revealed that in Turkey, little attention is given to workspace design and its acoustic requirements, despite apparent solutions such as using carpet as floor finishing materials and partially employing sound-absorbing materials in the ceilings. An essential result of the research is that even in currently designed and existing offices, acoustic performance can be increased by applying simple yet effective strategies. This way, the work environment of open office call centres will be humane, and at the same time, employees will be healthier and more effective. However, it would still be a more effective way to design and organise call centres in designated spaces from scratch, considering their particular needs and requirements towards the satisfaction and productivity of employees.

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