DYNAMIC ACOUSTIC MANAGEMENT IN OPEN-PLAN OFFICES: A CASE STUDY ON ACTIVITY-DRIVEN MOBILE PARTITIONS AND ADAPTIVE CEILING PANELS

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Abstract

Open-plan offices frequently struggle to balance speech privacy and speech intelligibility, which can degrade productivity and occupant well-being. This study investigates how acoustic conditions in an open-plan office can be improved using adaptive acoustic elements, including mobile partitions and height-adjustable island-type ceiling panels, both manually and robotically operated. These elements can be reconfigured to support different activity types such as collaboration, communication and focused work. Room acoustic measurements and simulations were performed to evaluate performance against ISO 22955:2021 - Acoustic quality of open office spaces. Activity types were represented through 21 different layout configurations with multiple acoustic element set-ups and combinations. Acoustic performance was assessed using key acoustic parameters related to speech like DA,S, D2,S, Lp,A,S,4m and reverberation time. The results show that changing the position, height and configuration of acoustic elements has a measurable impact on these parameters. Some configurations achieved higher speech attenuation values and lower reverberation times, while others produced different balances between spatial decay and reverberant conditions. The findings also highlight the influence of ceiling height on the effectiveness of partitions. These results provide different insights for designing activity-based acoustic environments that can dynamically respond to changing office use.

Keywords: *open-plan office acoustics, adaptive acoustic elements, speech privacy, activity based working, ISO 22955*

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1. Introduction

1.1 Background and problem statement

Open-plan offices now dominate knowledge-based industries, largely because they support spontaneous interaction and flexible work arrangements [1,2]. This spatial openness however, creates a persistent acoustic conflict: the simultaneous need for speech privacy and speech intelligibility [3]. Workers performing focused tasks are disrupted by nearby conversations, while collaborating teams must speak over ambient noise creating demands that no single static acoustic environment can satisfy. Surveys consistently show roughly half of open-plan workers are dissatisfied with acoustics, with intelligible irrelevant speech cited as the leading distraction [4].

Beyond comfort, exposure to intelligible background speech measurably impairs working memory, reading comprehension and broader cognitive performance [5,6]. As hybrid work compresses office use into fewer, more acoustically intense hours, the gap between static acoustic design and fluctuating occupancy demands poses a growing challenge for workplace designers and facility managers.

1.2 Adaptive acoustic solutions

Conventional open-plan office acoustics relies on passive treatments: sound-absorbing ceiling systems, partial-height partition screens, wall panels and raised-floor solutions [7,8]. These interventions reduce reverberation time and attenuate speech propagation, with ceiling absorption identified as the single most effective parameter for improving spatial decay [9]. Screen height interacts significantly with ceiling absorption: higher screens increase speech attenuation, but their effectiveness depends critically on the absorption properties and geometry of adjacent surfaces, including ceiling height [9,10].

Despite the gains these passive solutions achieve, they remain inherently static, and therefore structurally misaligned with the dynamic activity patterns of spaces that may support focused individual work, small-group collaboration and remote communication within the same day [11]. This mismatch has driven growing research interest in adaptive and reconfigurable acoustic systems, including height-adjustable ceiling panels, movable partition screens and sensor-integrated environments capable of modulating acoustic conditions in response to real-time or pre-scheduled activity patterns [12,13]. ISO 22955 [14], which sets activity-based acoustic performance targets for open-plan offices using parameters such as speech level decay per distance doubling ($D_{2,S}$), speech attenuation between locations ($D_{A,S}$), speech level at 4 meters ($L_{p,A,S,4m}$) and reverberation time, now offers a standardised framework for evaluating these adaptive systems consistently and reliably.

1.3 Research objectives and scope

Despite growing conceptual interest in adaptive acoustic systems, empirical evidence documenting their performance under systematically varied configurations in real or realistic office environments remains limited [12,13]. This study addresses that gap by investigating the acoustic impact of manually and robotically operated adaptive elements, specifically movable floor screens and height-adjustable island-type ceiling panels, across configurations designed to support distinct activity types, including focused work, communication and collaboration. Room acoustic measurements and validated simulations evaluate performance against the ISO 22955 framework.

The central research question is: to what extent do adaptive acoustic elements produce measurable changes in key speech-related acoustic parameters and how do spatial configuration and ceiling orientation influence these outcomes? This case study contributes grounded insights for activity-based acoustic design, demonstrating that reconfigurable elements can dynamically tailor an open-plan office's acoustic environment to changing occupancy and work patterns. Future implementation of integrated sensor systems and pre-scheduled pattern recognition will enable real-time activity identification, bridging acoustic measurement with dynamic workspace management.

2. Research methodology

2.1 Experimental setup and office Layout

The acoustic measurements were conducted in an open office located on the Arenberg Campus of KU Leuven (BE) as shown in Figure 1. The office has a floor area of approximately 9.6 × 9.45 m and includes seven windows distributed across three sides of the room. On the north side, the entrance door and a meeting room which is separated from the main office area by a glass wall, as shown in Figure 2.

Following the spatial design proposed by the architectural firm UN Studio (UNS) Amsterdam (NL), the office contains 14 workstations in total. These workstations are arranged into four work islands of different sizes: two two-person islands located in the west and east corners, one four-person island positioned next to the meeting room, and one six-person island situated in the south corner, as shown in Figures 2 and 3.

To support different work activities and acoustic conditions, mobile partitions were placed in different locations and orientations to create four office layouts. These layouts were designed to accommodate various scenarios, including video or phone calls in booth-like settings, focused individual work and collaboration among groups of different sizes.

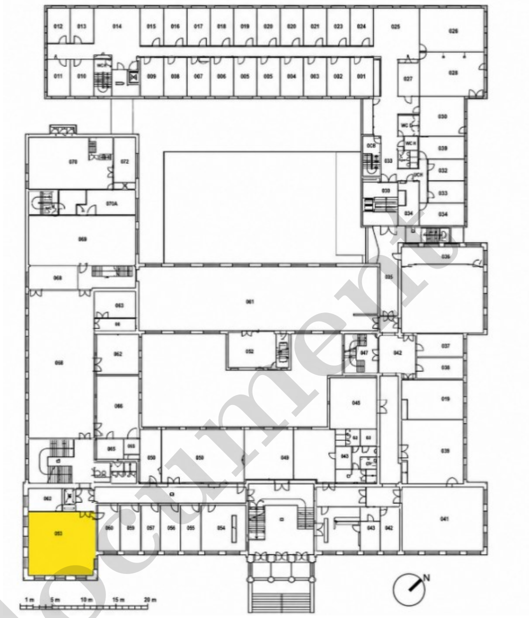

Figure 1. The office is marked in yellow in the layout.

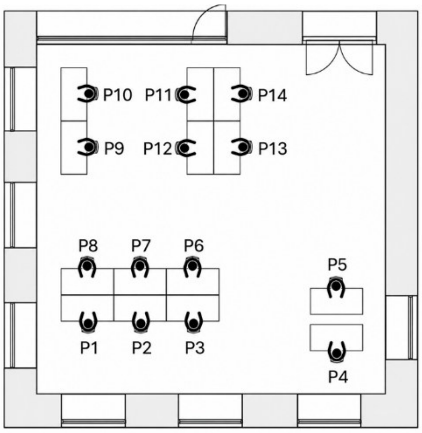

Figure 2. Furniture layout including worker station ID (P1 – P14)

Figure 3. Work stations and furniture layout

2.2 Adaptive acoustic elements

The main adaptive acoustic elements in the office consist of six custom made mobile partitions and 36 suspended acoustic ceiling panels (Rockfon Canva® Island), as shown in Figure 4.

Each mobile partition measures 1340 × 306 x 2100 mm (L × W × H). The lower parts of all six partitions are made of the same material. Two of the partitions are equipped with integrated actuators, allowing the entire partition to move automatically. Based on the surface materials applied to the upper parts, the partitions can be classified into three types with different acoustic properties: four partitions with sound-absorbing material (all sides with 40 mm stone wool behind textile), one partition with sound-absorbing material on one side and a whiteboard surface on the other, and one open partition with shelves, as shown in Figure 5.

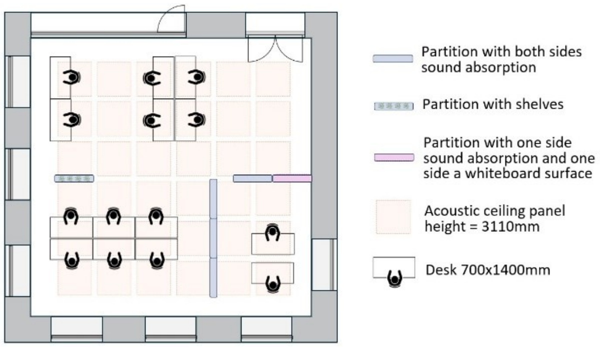

Figure 4. Placement of ceiling panels and partitions

Figure 5. Three different types of partitions

The 36 acoustic ceiling panels (57% ceiling coverage) have identical dimensions of 1200 x 1200 x 60 mm (L x W x H). Two of these panels are individually equipped with three motors installed above the scaffolding structure, enabling their height and orientation to be adjusted automatically. These robotic ceiling panels can move within a height range of 2.1 m to 3.0 m and can be tilted up to 30 degrees in any direction. The remaining 34 acoustic ceiling panels are each suspended by four metal cables attached at the corners. Their height and orientation can be adjusted manually by changing the cable lengths.

2.3 Configurations tested and activity mapping

For each office layout, multiple scenarios were tested during the acoustic measurements. These scenarios included different configurations of the ceiling panel, minor repositioning of the mobile partition, such as moving it closer or connecting it to the wall, as well as different measurement types and directions. In total 21 scenarios were tested. As to the office layout without partition, there are 6 layout scenarios (ID: 2, 3, 3d, 4, 4d, 6). Configuration ID 3 is shown in Figure 7, ID 4 is shown in Figure 8. As to the office layout where a half-closed zone was created for two occupants with six partitions, there are 12 layout scenarios (ID: 2Pr, 2Pl, 2PWr, 2PWl, 5Pr, 5Pl, 5PWr, 5PWl, 7Pr, 7Pl, 7PWr, 7PWl). Configuration ID 2Pr is shown in Figure 4 and 5. Configuration ID 2PWl is shown in Figure 6. As to the office layout where a half-closed zone was created for two occupants with five partitions, there is only one scenario (ID:8). As to the office layout where two half-closed zones were created for two occupants with six partitions, there are 2 scenarios (ID: 8P, 8PW).

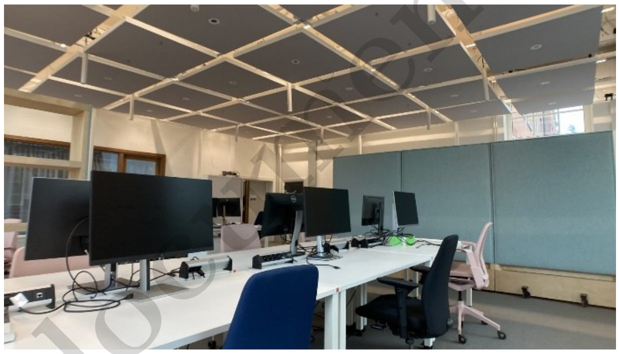

Figure 6. Configuration 2PWl, with ceiling panels at 3110mm height, including partitions

Figure 7. Configuration 3. with ceiling panels at 2100mm height

Figure 8. Configuration 4. with tilted ceiling panels from 3110-2500mm.

2.4 Standard ISO 22955 and compliance framework

ISO 22955:2021 - Acoustic quality of open office spaces, defines six "space types" based on the activity in the space; vacant floor plate (Space Type 1), outside of the room communication/telephone (Space Type 2), nearest-workstation collaboration (Type 3), low-collaboration and individual work (Space Type 4), public-facing reception (Space Type 5), and combined activities (Space Type 6). Each type carries target: workstation noise level ($L_{Aeq,T}$) and required acoustic values: reverberation time (T_r), in-situ speech attenuation ($D_{A,S}$), spatial decay rate of speech ($D_{2,S}$) and speech level at 4 m ($L_{p,A,S,4m}$). This research focuses specifically on Space Types 2 to 4, and 6 as these best reflect the activity range investigated in the test setup. The corresponding values for Space Types 2 to 4 are summarized in Table 1. For Space Type 6 potential $D_{A,S}$ ratings between different types of spaces range from 15 to 32 dB(A) [14].

Table 1. Acoustic parameters ISO 22955 (Space ype 2-4).

Space Type	$L_{Aeq,T}$ [dB(A)]	$D_{A,S}$ [dB(A)]	T_r [s]	T_{125Hz} [s]	$D_{2,S}$ [dB(A)]	$L_{p,A,S,4m}$ [dB(A)]
2.	< 55	≥ 6	≤ 0.5	≤ 0.8	≥ 7	≤ 47
3.	< 52	≤ 4	≤ 0.5	≤ 0.8	≥ 8	≤ 48
4.	< 48	≥ 6	≤ 0.5	≤ 0.8	≥ 7	≤ 47

3. Acoustic measurements and calculations

3.1 Acoustic calculations and simulations

The application of acoustic simulation can extend room acoustic assessment by evaluating acoustics at positions not measured in the real world. To validate the ability to simulate room acoustics within the ISO 22955 framework, selected configurations were simulated across scenarios, addressing $L_{p,A,S}$ (global A-weighted values at the measurement point) and $D_{2,S}$ (rate of spatial decay of the A-weighted sound pressure level of speech per doubling of distance). Treble SDK has been used as an acoustic simulation engine [15]. The simulation setup included three stages: room modeling, simulation, and postprocessing.

Room modeling includes two phases. First, create a 3D geometry of the room, furniture, and movable components according to a configuration scenario and in a way that satisfies Treble requirements, such as a closed outer shell (watertight), while keeping fine geometric details to a minimum to optimize runtime. Second, define acoustic properties for the geometry's surfaces by assigning acoustic materials from the predefined Treble material library.

The acoustic simulation requires importing the geometry into the simulation with material attributes; configuring and positioning the source and receiver according to a scenario; defining the simulation; running the simulation; and extracting results. To balance accuracy and runtime, the proposed approach employs a hybrid simulation that combines Discontinuous Galerkin (DG) and Geometrical Acoustics (GA).

Postprocessing translates the sound pressure level (SPL) across frequency bands from the simulation into an A-weighted ISO-mapped total pressure level comparable to $L_{p,A,S}$ in accordance with ISO 22955, which is then used to deduce $D_{2,S}$. The simulation engine by default uses an omnidirectional source with an SPL of 94.0 dB(A), while ISO 22955 requires a source with A-weighting across frequency bands. Accounting for this, across all frequency bands, the algorithm maps the SPL by converting to power and applying the A-weighting correction to $L_{p,A,S}$.

3.2 Acoustic measurements

The measurements were performed with a Norsonic Nor140 sound level meter calibrated with a Norsonic Nor1251 calibrator. The sound sources were an Akron Qsources Qam/QOhm omnidirectional sound source and amplifier for determining the sound level measurements and a Larson Davis BAS006 impulsive sound source for determining the reverberation time measurements. For the measurement $L_{Aeq,T}$, $D_{A,S}$, $D_{2,S}$ and $L_{p,A,S,4m}$, the source was placed at a workstation position close to a wall at 1.2 meter above floor level, while measuring at 1.2 meter above floor level on a more or less straight line away from the source, according to ISO 22955.

4. Data Analysis and Results

4.1 Baseline acoustic conditions

The reverberation times $T_{250-4000}$ ranged around 0.50 to 0.69 seconds, the lowest values for the configurations where the ceiling panels were on their lowest position. This agrees with the Sabine relationship stating that the reverberation time is directly proportional to the volume of the room. When the room was partitioned, the reverberation time went down to 0.31 seconds in the smallest part of the room. The speech levels are impacted mostly by the presence of partitions, blocking the direct sound propagation of sound. Moving the partition as close as possible to a wall is secondarily important as it reduces the importance of a first-order wall reflection. There is also a clear relationship with the reverberation time and thus with the volume of the room (part): the smaller, the lower the speech levels and all related measured quantities according to ISO 22955.

4.2 Validation of calculations

To validate simulation results against real-world measurements, we compared 69 $L_{p,A,S}$ pairs (Figure 9) and 21 $D_{2,S}$ pairs, each computed across configurations with three receivers per source (Figure 10).

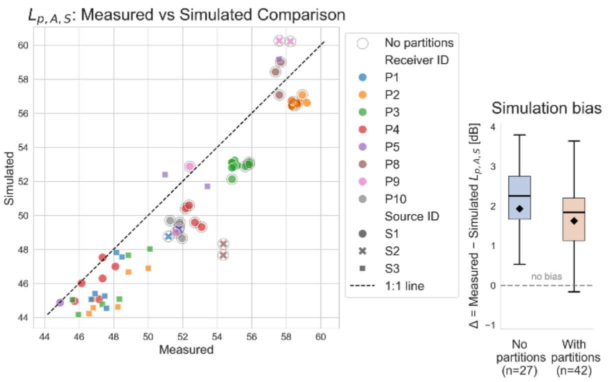

Figure 9. Comparison of $L_{p,A,S}$ between real-world measurements and simulations

Simulations used a hybrid solver that switched from DG to GA at a crossover frequency of 355 Hz.

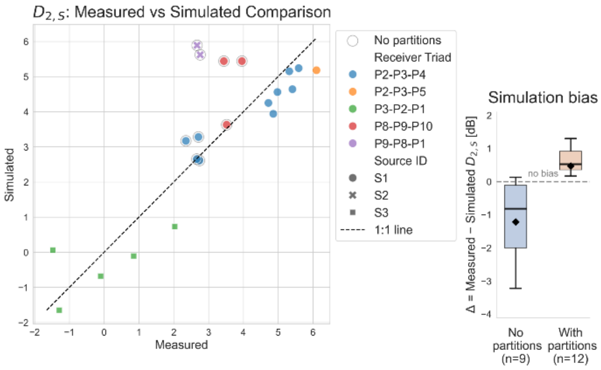

Figure 10. Comparison of $D_{2,S}$ between real-world measurements and simulations, and distribution simulation bias with and without partition.

Overall, simulated and measured values track each other closely in shape but not in level. For $L_{p,A,S}$, simulations consistently read quieter than measured, by about 1.75 dB(A) on average (95% confidence interval (CI): 1.4 - 2.1 dB(A)), regardless of source-receiver distance or source position. For $D_{2,S}$, there is no overall bias (mean −0.25 dB(A), CI: -0.8 to 0.3), but this depends on partitions: without partitions, simulations overpredict decay by roughly 1.2 dB(A) per distance doubling, and inconsistently so; with partitions present, the error drops to about +0.5 dB(A) and becomes noticeably more consistent.

4.3 Impact of components

4.3.1 Effect of partition configurations

Partition presence consistently improved speech-related parameters: $D_{2,S}$ increased by approximately 2 - 3 dB(A), $L_{p,A,S,4m}$ decreased by 2 - 6 dB(A), and $D_{A,S}$ reached 9 - 13 dB(A) depending on placement, compared to near-zero or negative $D_{A,S}$ without partitions. Positioning partitions flush against the wall ("PW" configurations) yielded a further 0.5 - 3 dB(A) improvement over partitions placed away from the wall ("P"), by blocking first-order reflections. Proximity to the source mattered more than proximity to the receiver: partitions near the source produced larger $L_{p,A,S,4m}$ reductions (4 - 5 dB(A)) than identical partitions positioned near the receiver.

4.3.2 Effect of ceiling panel height

Lowering ceiling panels from 3.11 m to 2.10 m (Figure 7) reduced reverberation time $T_{250\text{-}4000}$ from 0.69 to 0.59 seconds and with tilted (Figure 8) 0.62 s. An overview of measured reverberation times per octave band are shown in Table 2. Ceiling panel height/tilt had negligible effect (<1 dB) on direct-path speech levels when no obstruction was present, since the direct sound path dominated. Where direct paths were blocked (e.g., by monitors), tilted or lowered panels reduced reflected sound traveling over the panels, improving speech levels by up to 4 dB(A) at distant positions. Panel height showed minimal influence on $D_{A,S}$ behind partitions.

Table 2. Measured reverberation times T_r (sec.)

Ceiling height (mm)	Frequency (Hz)					
	125	250	500	1000	2000	4000
3110	0.99	0.80	0.62	0.61	0.70	0.71
3110-2500	0.99	0.80	0.62	0.49	0.60	0.62
2100	1.11	0.84	0.60	0.47	0.49	0.55

4.3.3 Combines system performance

These results confirm that ceiling panels and partitions serve distinct, complementary acoustic functions. Ceiling panels primarily govern reverberation time and overall room 'liveliness', while partitions (and incidentally, monitors) control direct sound transmission and $D_{A,S}$, the parameter most tied to ISO 22955 discretion requirements. These findings indicate that different workplace activities require different acoustic configurations: collaborative areas benefit from moderate reverberation and speech intelligibility, whereas focused and concentrated work require stronger spatial attenuation through combined ceiling adaptation and partitioning. The wall-adjacency effect further demonstrates that partition geometry, not just presence, is critical, since misplaced partitions sacrifice up to 3 dB of available attenuation.

4.4 Interpretation of findings

The results show that speech privacy and speech intelligibility cannot be achieved with a single fixed room configuration. Instead, different activities require different acoustic settings. Partitions have the greatest influence on reducing direct sound transmission, while ceiling height and tilt mainly affect reverberation and become more important when the direct sound path is blocked. For adaptive systems, this means partition movement should be the primary control strategy when speech privacy ($D_{A,S}$) is the main objective, with ceiling adjustment providing additional optimisation. The Space Type 6 results highlight this trade-off: wall-connected partitions can separate telephone and collaborative activities, but focused work still requires the stricter acoustic conditions defined for Space Types 2 or 4.

4.5 Design guidelines for adaptive acoustic systems

Ceiling treatment should generally prioritise sound-absorbing surfaces over reflective ones, such as bare concrete or gypsum board. Full ceiling coverage with a weighted sound absorption coefficient (α_w) close to 1 is recommended [14] to help control the reverberation time, while lowering the ceiling further reduces the effective room volume and, as a result, shortens the reverberation time even more. That said, for improving speech privacy specifically, screens and partitions should remain the primary control strategy. Partitions should ideally be positioned close to the noise source, extend flush to adjacent walls wherever possible. To maximise sound attenuation between workstations they should have a height exceeding 1.5 m [14]. Evidence from ISO 22955 (Table 7) also shows that partition attenuation is substantially higher beneath sound absorptive ceilings, which makes ceiling absorption an essential precondition for maximising partition effectiveness in open office spaces.

4.6 Limitations and future work

This study was conducted in a single room with dimension 9.45m × 9.6m, smaller than typical open-plan offices, with rear-wall reflections potentially understating $D_{2,S}$ and rC values. Measurements used three microphone positions instead of the four recommended by ISO 3382-3. Parallel work investigating occupant comfort (survey and interviews) within the space is still ongoing and unavailable for inclusion. Future work should validate findings in larger, multi-zone offices with full-length measurement lines.

5. Conclusion

This case study demonstrates that adaptive acoustic elements can measurably reconfigure open-plan office acoustics. Partitions improved $D_{2,S}$ by 2 - 3 dB(A) and $D_{A,S}$ up to 9 - 13 dB(A), with wall-flush placement adding a further 0.5 - 3 dB(A). Ceiling panels alone reduced reverberation time from 0.69 s to 0.59 s; combined with partitions, this dropped further to 0.53 - 0.50 s. Hybrid DG/GA simulation reproduced measured trends closely, with a consistent ~1.75 dB(A) underprediction in $L_{p,A,S}$ and partition-dependent accuracy in $D_{2,S}$, supporting its use for pre-deployment design exploration once these biases are corrected for. Measured data show the room does not comply with Space Type 2, 3 and 4 under ISO 22955. Only for Space Type 6, where $D_{A,S}$ determines whether different functions can coexist in one open office, were values of about 12 dB(A) are sufficient, specifically for pairing *informal meeting* (large part) with *outside-room communication* (small part), and *outside-room comm*unication (large part) with *collaborative work* (small part). Other combinations did not meet requirements.

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