HVAC Sound Levels and Facilities Management Priorities in an Educational Laboratory

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ABSTRACT

HVAC operation can lead to noise issues in instructional laboratories, but preliminary studies may not determine the source or find a means of control. We analyzed reported sound levels in Building Services Technology Laboratory at Universiti Tun Hussein Onn Malaysia in Pagoh and solicited feedback from respondents to guide our diagnostic efforts. Data on sound levels was collected using PM6708 sound level meter for two minutes at 12 different locations during HVAC operation. The sample size consisted of 60 participants selected based on purposive sampling method. The reported levels ranged from 63.7 to 68.5 dB(A) and the average of the values obtained was 65.0 dB(A) with standard deviation of 1.4 dB. Assessed levels were equal to 65.2 dB(A). All respondents agreed that the presence of sound is disruptive, constant and that sound travels through vibrations. These answers point to apparent rather than substantiated problems or documented learning impacts. We suggest performing reference measurements on baseline parameters and checking for the condition of equipment before maintenance or selective changes in the vibration, ducting, and room treatment. There was no experimentation. Insufficient data in terms of time history, lack of pretest calibration data, and coupling of measurements made without HVAC in operation limited the acoustic dataset to descriptive analysis without any attribution to HVAC alone.

Keywords: HVAC; laboratory acoustics; noise assessment; facilities management; maintenance prioritisation

INTRODUCTION

HVAC systems promote thermal comfort and indoor environment quality. However, the fans, motors and ducts may produce noise pollution and vibration. A recent study identifies mechanical excitation, turbulence and transmission as factors that lead to noise pollution (Ouis et al., 2025). Research on schools has demonstrated that the acoustic quality effects communication, ability to concentrate and health (Mealings, 2023; Mercugliano et al., 2025; Razali et al., 2024; Zhang, Wong et al., 2024). The distinct elements of the impact of noise are either studied in laboratory (Braat-Eggen et al., 2021) or classroom level (Oktav et al., 2025). While those findings encourage further study, they do not show the source of the noise nor its consequences for studies in particular laboratories.

The facilities management has to deal with acoustic problems linked to services, requiring actions that will safeguard ongoing activities being supported by the facility. The decision of the manager is based on whether routine maintenance will be sufficient or specialized diagnosis and capital modifications would be required. The decision will be based on the evidence available as well as on the impact of the mitigation measures on

the functioning of the building. Thus, management of maintenance provides the connection between the acoustic assessment and the main duties of facilities management (Awang et al., 2014; Omar et al., 2024).

The study of ventilation and acoustics must be performed simultaneously. Changes made to ventilation will have an effect on acoustics, and it is possible to alter the characteristics of duct systems, which will reflect on sound transmission. Therefore research studies use to investigate acoustic properties with regard to ventilation and other indoor environment requirements of educational facilities (Aguilar et al., 2023; Baba et al., 2024). Numerical investigations on flexible-absorbent ducts provide evidence of possibilities for attenuation (Afsar et al., 2024). Acoustic detection and vibration measurements represent complementary methods of diagnosing equipment (Forouharmajd et al., 2021; Grigg et al., 2021). Reviews of HVAC design and assessment of noise in space also point to the necessity of studying HVAC equipment, transmission routes and reception areas (Fiorini et al., 2023; Ruan & Yin, 2021).

Recent research has also provided insight into the limitations of a single A-weighted level when describing an occupier's perception of air-conditioning sound. In 2026, Ma et al. integrated time-dependent psychoacoustics with subjective listening tests to determine perceived sound quality. Their method allows for more complete sound data to be collected when the disturbances caused by the sound persist, but it does not invalidate the use of a rudimentary survey beforehand.

Campus facility managers can use a screening questionnaire to identify a problem that needs further investigation without necessarily finding its root cause. Operators can indicate priorities in managing the operations, but acceptance of the suggested mechanism does not mean that instrumentation gives confirmation. Acoustic targets are different in their descriptions and measurement procedures (Tardini et al., 2025). Therefore, a proper evaluation must make a link between observations and particular tests, as well as document the reasons for each choice. This obligation is in line with the function of operational data in building maintenance (Omar et al., 2024). The evidence on synergistic impact of indoor environment is also reason for verification of acoustic indicators against the ventilation and air quality standards (Deng et al., 2023).

According to the research published by Awang et al. (2019), the findings from Amirul Faiz Abdul Latif conducted assessments of ten laboratories with the help of questionnaires filled by the inhabitants, sound measurements taken with five minutes' time within six experts. The professional interviewed indicated that the location of blowers and the arrangement of return air are the factors which lead to poor acoustics and hence, the authors come to conclude that acoustic treatment should take place and the return air should be relocated, but no verification was made on the part of the researchers. The study being performed is based on above-mentioned research and performed 12-position study in one laboratory together with response from the personal, distinguishing between observed cases, the way they are perceived as well as measures which need to be taken for further research.

Campus acoustic evaluations have relied on the assessment of background noise and reflexion to detect areas that need enhancement. Nonetheless, a preliminary laboratory analysis may not provide the data needed to distinguish between the origin of an equipment source and its transmission mechanism. The practically relevant issue is how to utilize such limited field evidence and the responses provided by personnel to come up with the right sequence of performing diagnostic and maintenance procedures. We introduce the source-path-receiver scheme to account for the measured conditions, the recognized mechanisms, and the suggested methods.

An initial exploratory study was conducted in a laboratory in order to measure A-weighted sound levels at 12 positions during HVAC operations, while also gathering staff opinions on the noise entering the space and the mitigation measures available. This was then used for formulating a two-phase diagnostic and maintenance process. No remediation was applied, therefore the study does not provide any estimates of noise reduction, cost savings or improvement in learning outcomes.

MATERIALS AND METHODS

Study design and site

We assessed the Building Services Technology Laboratory at Universiti Tun Hussein Onn Malaysia (UTHM), Pagoh, in a cross-sectional case study. The field survey recorded sound levels while the air-handling unit (AHU) was operating. The laboratory was selected following a preliminary survey of eight engineering laboratories on campus. A structured questionnaire provided personnel perceptions of the laboratory HVAC system and possible mitigation measures. We considered both evidence sources when formulating recommendations, while keeping measured sound levels distinct from perceived mechanisms. Acoustic simulation was not completed, and no physical intervention was tested. Figure 1 shows the laboratory layout, including the bench arrangement, the door openings and the adjoining raw-materials and preparation rooms. The plan is a photograph of the laboratory's light-switch layout sign; it has no scale, does not show the AHU or ducting, and does not mark the measurement positions. The numbers on it (1–6) denote light-switch groups and are not measurement positions.

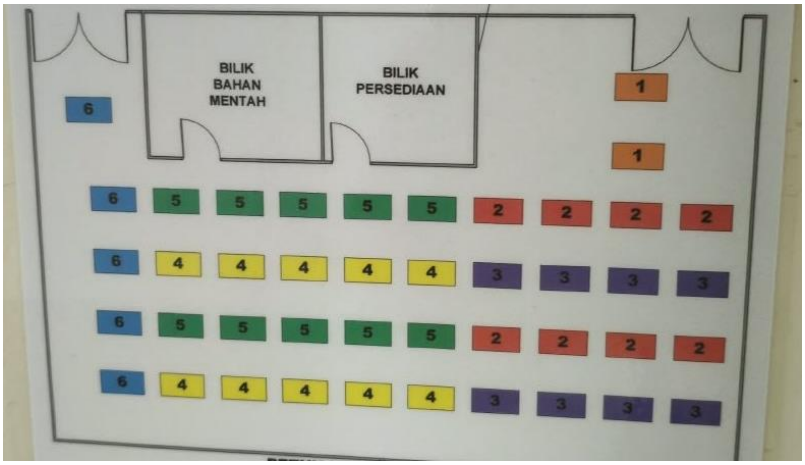

Figure 1. Floor plan of the Building Services Technology Laboratory

Figure 2 summarises the preliminary survey of eight engineering laboratories from which the study laboratory was selected. These preliminary measurements were taken during the semester break, when students were not present, and are presented as logarithmic averages. The Building Services Technology Laboratory recorded the highest average (65.3 dB(A)), followed by the Geomatic (60.8 dB(A)) and Geotechnical (60.3 dB(A)) laboratories.

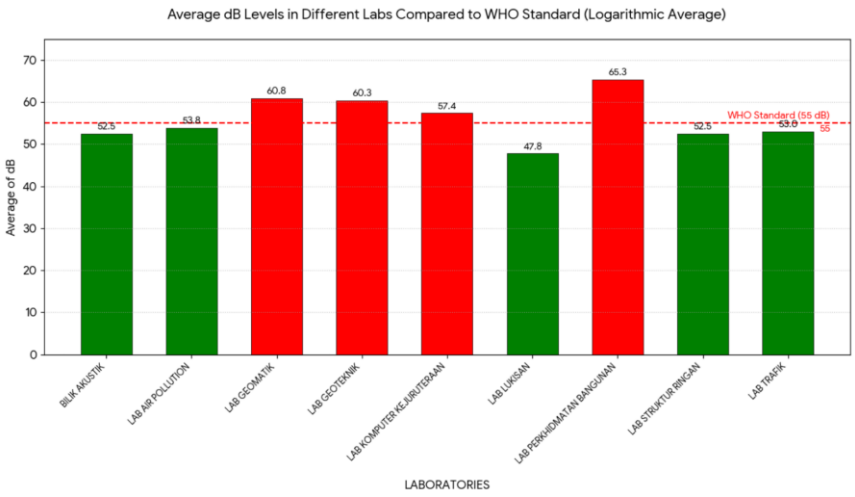

Figure 2. Logarithmic average sound levels in eight engineering laboratories during the preliminary survey (semester break, students absent).

Field protocol and acoustic descriptors

A total of 12 locations were surveyed during this field survey. With the help of the Peakmeter PM6708 sound-level meter, a period of two minutes was allocated for measurements at each location when the AHU was functioning. One registered A-weighted value is mentioned as the dataset from each location. Even though the report given for the project makes it clear that the value is referred to as LAeq and also mentions that some calibration was done before taking measurements, there is no information regarding the calibrator, reference level, observed levels, or date of the report. There is no evidence to support time history or method of calculations used. The laboratory has a calibration report pertinent to the PM6708 equipment (serial number H11J-B02889, report number PC261363L4, Premier calibration Sdn. Bhd) which contains reference sound level calibrator which is a USA based level calibrator. The equipment was calibrated on the 5th of May 2026 which was after the finalization of the project report dated January 2026. At a frequency of 1 kHz, the instrument recorded sound pressure levels of 93.9 dB and 113.9 dB where the corresponding reference levels are 93.4 dB and 113.2 dB indicating that the corrections are −0.5 dB and −0.7 dB with uncertainty of measurement of ±0.5 dB (k = 2). The aforementioned corrections have not been used while calculating the level. The calibration certificate is covering the aforementioned two levels measured at 1 kHz; all the tested sound levels are higher than 63.7–68.5 dB (A) levels indicated in this paper. Thus, it has not been tested how performed frequency weighting, time weighting and linearity of the sound level meter at these sound levels used for measurements. Thus, there is no description of the method used for sound levels choosing or accumulating. We describe the values as reported point sound levels rather than verified equivalent-continuous sound levels. Occupancy conditions are not consistently documented. We calculated the arithmetic mean, sample standard deviation, median and range to summarise variation between positions. An equal-weight energy-based spatial summary was also calculated because the decibel scale is logarithmic:

$$L_{sp,E} = 10 \log_{10} \left[\frac{1}{n} \sum 10^{(L_i/10)} \right] \quad \text{for } i = 1, \ldots, n \qquad (1)$$

Here, Li is the reported A-weighted sound level at position i and n = 12. Each position receives equal weight. The indicator summarises the reported levels across the selected positions; it is not a temporal average, a room-wide exposure estimate or a measure of the HVAC contribution alone.

Questionnaire, participants and analysis

The survey comprised data regarding respondent's persona, perceived HVAC noise situation, and response such as possible solutions that they come up with. Agreement scale used a scale of 5 representing Strongly Agree being at the other extreme. A small pilot study was undertaken with other participants that included a total of 30 respondents who were not part of the main sample. The reported cronbach's alpha was found to be 0.978 for a total of 50 items used in the study. The coefficient does not describe what constructs do the items relate to or whether content validity is present; it is possible that high value indicates presence of item redundancy. The main report that uses 47 items does not show the variations at the item level. In the present article only nine items are selected for analysis and evaluation. The items selected are aimed at areas of disruption, ducts and vibration pathways and also involve solutions for maintenance or reconstruction.

In the present case, purposive sampling has gone on to yield 60 responses that have been calculated by taking in 9 from UTHM Pagoh Facility Management and 51 from Sime Darby Property Selatan. The team responsible for the creation of this survey is characterized as members of the personnel engaged in the work of HVAC equipment utilization and maintenance. In total, the research is based on a diversity of maintenance or laboratory roles that people hold; that is why the sample has received its name as the personnel rather than being limited to the acoustical professionals who possess relevant accreditation. As for the distribution of experience in the obtained results, we have 35 respondents who have had 6 to 10 years of experience, 23 respondents who have had less than 5 years, and 2 respondents with no experience. Totals for the nine listed theoretical issues all correspond to 60, and their results are presented as frequencies and percentages. The only thing connected with SPSS calculations refers to 47 responses after listwise missing data has been omitted; and the results already received from SPSS are not utilized in the present research.

Information about the study has been provided to the participants prior to their agreement to take part, and their responses have been kept anonymous. No identifying data of the respondents is provided. No reference

for institutional ethics approval or exemption can be found in the documentation of the study. The processes of voluntary participation of the subjects and the process of anonymization are mentioned, but they are not suggested as alternative to institutional ethics review.

Evidence integration and decision rules

The field observations and focal survey responses were organized within a source-path-receiver matrix. Results were classified into three categories: descriptions of the room condition, perceived pathways, or proposed controls. The field data described variations between positions during the same campaign. Personnel responses provided contextual evidence from a sample of individuals well-versed in campus HVAC operations. Individual levels of involvement were not reported, and the questionnaire included some acoustic information as part of its statements. Survey agreement was therefore not considered independent verification of a site-specific mechanism. Establishing a physical route would require further spectral, airflow, or vibration measurements.

We suggested a hierarchical approach based on factors such as the necessity of diagnostics, reversibility, disruption and impact on airflow, hygiene and energy consumption. First, it is necessary to perform baseline measurements and regular maintenance operations that could help to form a clearer picture of the problem before applying design solutions. Whether ducts or rooms are to be treated depends on results of subsequent analyses. There were no numerical assessments, cost comparisons or formal optimisation processes; the proposed order is just an engineering recommendation that has never been validated experimentally.

Data-quality checks and reproducibility

We have verified the 12 acoustic indicators with the use of Table 4.1 of the undergraduate project report, and we calculated the geographical summaries again without rounding the intermediate logarithmic indicators. The focal response counts were also verified with the thesis tables, graphical presentations and organizational summaries, with each totaling 60. The pilot sample of 30 respondents, the major sampling of 60 respondents and a wholly different dataset of 47 complete cases were treated in a different way. Through verification of these data, consistency was demonstrated between calculations and data in the manuscript. However, the dataset of respondents and primary measuring logs were not available for independent verification.

Both Table 2 and Figure 3 show the levels of noise detected at 12 different locations, while Figure 4 shows the response levels and counts at each point of observation. Together with Eq. (1), the data here illustrate how the calculations are made. Repeating the study would additionally require a scaled plan of the test room, which shows measured points (Fig. 1 is not the one), height and orientation of microphones, dates and times of measurements, details and calibration history of measuring instruments used, instrument setup, etc. Measurements of fan speed, damper position, air flow, equipment load should be recorded together with the results of acoustic measurements. In interpreting the findings, we distinguish spatial variation from temporal persistence, personnel perceptions from confirmed mechanisms and proposed actions from tested interventions. We do not assess regulatory compliance because the required acoustic descriptor, measurement protocol and instrument traceability for the measurement period were unavailable. Follow-up testing is specified for each proposed control, together with checks for ventilation, hygiene and energy consequences.

Table 1. Measurement and interpretation safeguards

Component	Implementation	Interpretive safeguard
Site and condition	One laboratory; HVAC operating during a single campaign	Occupancy descriptions inconsistent; no matched off-state or repeatability assessment

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Spatial sampling	12 predefined positions; two minutes per position	Measurement positions not marked on the available plan (Figure 1); microphone coordinates and height unavailable
Instrument	PM6708; A-weighted observations	Value extraction unspecified; calibration before the campaign stated without records, and certificate dated 5 May 2026 post-dates the campaign; no time histories or spectra
Survey	60 purposively sampled personnel	Campus HVAC personnel; individual involvement not reported; perceptions do not verify mechanisms
Analysis	Descriptive spatial and item-level summaries	No causal or formal compliance inference

RESULTS AND DISCUSSION

Spatial sound-level pattern

The 12 point levels analyzed reported readings between 63.7 and 68.5 dB(A) (Figure 3). The mean was 65.0 dB(A), whereas the standard deviation obtained was 1.4dB and median value calculated was 64.8 dB(A). The equal-weighted energy-based spatial index was noted at 65.2 dB(A). P1 had the maximum value while P11 and P12 had minimum readings. The 4.8 dB range is evidence of the differences in the readings in place taken during field measurements.

As can be seen from Table 2, the reported amounts at all twelve positions have been included in the report and were taken with the students in the laboratory and the AHU working. The WHO and ANSI S12.60 reference values are included in the report with the calculated differences only for the sake of context and not for the purpose of analyzing non-compliance.

Table 2. Reported A-weighted point levels during HVAC operation with students present, with WHO and ANSI S12.60 reference values from the project report

Point	Measured LAeq (dB(A))	WHO limit (dB(A))	Difference (WHO) (dB)	ANSI limit (dB(A))	Difference (ANSI) (dB)
P1	68.5	50.0	+18.5	35.0	+33.5
P2	66.2	50.0	+16.2	35.0	+31.2
P3	65.9	50.0	+15.9	35.0	+30.9
P4	65.0	50.0	+15.0	35.0	+30.0
P5	64.8	50.0	+14.8	35.0	+29.8
P6	65.3	50.0	+15.3	35.0	+30.3
P7	64.1	50.0	+14.1	35.0	+29.1
P8	64.4	50.0	+14.4	35.0	+29.4
P9	64.7	50.0	+14.7	35.0	+29.7

P10	64.0	50.0	+14.0	35.0	+29.0
P11	63.7	50.0	+13.7	35.0	+28.7
P12	63.7	50.0	+13.7	35.0	+28.7

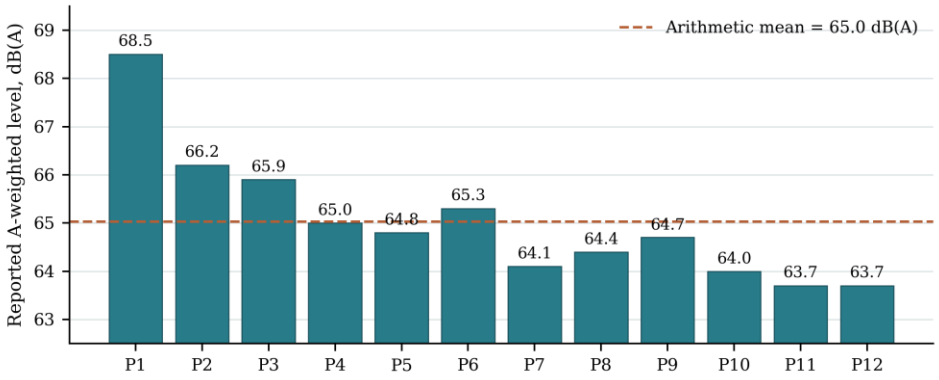

Figure 3. Reported A-weighted sound levels at the 12 measurement positions during HVAC operation.

These values provide a descriptive screening dataset for further investigation. They are not used to demonstrate non-compliance with a classroom criterion or an occupational exposure limit.

Personnel perceptions

Regarding the nine focus items, all 60 respondents chose Agree or Strongly Agree when responding to questions about disruption of teaching and learning, ongoing noise and vibration transmission. Return ducts and diffusers were identified as sources of interference by 59 respondents (98.3%). All 60 respondents favored acoustic liners, aeration redesign, frequent filter cleaning, and wall absorption, while 59 (98.3%) supported regular acoustic monitoring. The numbers for each category are shown in Figure 4. The above findings refer to the sample of the respondents rather than the effect of education or sound channels used.

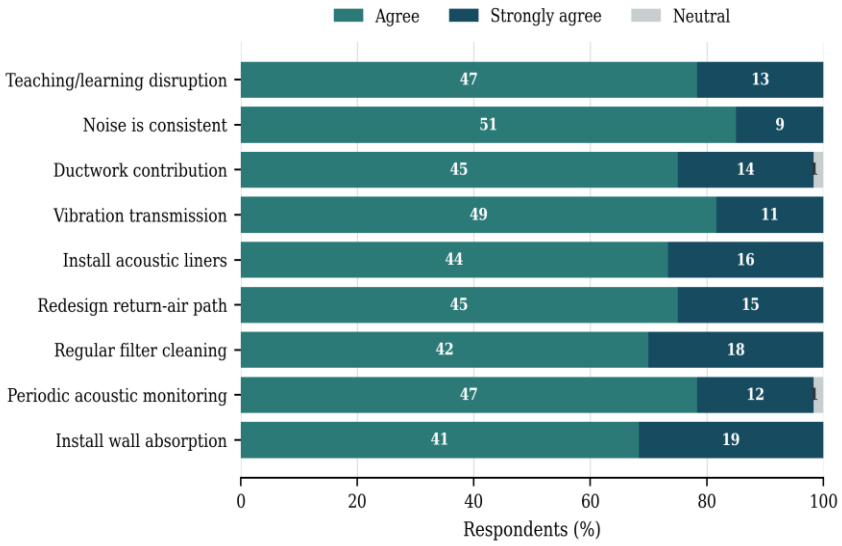

Figure 4. Responses to nine selected agreement items (N = 60). Labels are counts; item wording is abbreviated. No Disagree or Strongly Disagree responses were reported for these items.

The concentrated accord denotes a concession to all the things talked about in the sample. However, the answers to statements of the questionnaire revealed either a measured mean or a suspected mechanism of said items. One of the items mentioned a loss 5 dB to 10 dB and one more mentioned low-frequency absorption.

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These items produced influences on the answers of respondents though attenuation and frequency-related performances were not measured. Most respondents belonged to the same maintenance organization, and it was not reported who participated in the laboratory system. Thus, the results are rather informative for planning diagnostics as opposed to establishing the presence or absence of ductal friction, structure-borne transmission or educational impairment in the study. The research of students' sound perception provides basis for reference here (Zhang, Mui, et al., 2024), though the current investigation is not supposed to replace the evaluation of students' and teachers' effectiveness.

Direct results of education also call for task-oriented evaluation. In study of the students of the ages from 11 to 14 by Pellegatti, Visentin, Torresin, Babich and Prodi (2026) differences were established between sounds in terms of calculation reaction time, while there was no difference in reading comprehension and accuracy of calculations. These results cannot be directly transferred to the laboratory of the university or estimated from the questionnaires of personnel. They call for the evaluation of the activity being affected and the differentiation of perceived disturbance and an objective change in productivity.

Evidence convergence and inference boundaries

Table 3 divides captured pieces of evidence from conclusions and follow-up tests for every finding. Measurements in the field confirm sound was picked at each sampling location during HVAC operation. Survey results reveal that respondents experienced noise disruption and thought of it and different ways it might happen. Although these findings complement each other, their concurrence does not confirm existence of the same condition at every site. Consideration of duct and vibration ways remains a hypothesis, while proof of feasibility does not imply feasibility or performance after installation.

This categorization provides facility managers with the information they require in making upcoming measurement choices. When selecting a treatment proposal, one must first determine the source and/or transmission pathway of the target. After doing so, the efficiency of the treatment must be assessed in relation to airflow requirements, hygiene, and energy consumption. The matrix may organize observations and suggestions but cannot be taken for a genuine causal structure.

Table 3. Triangulation of evidence, supported inference and remaining test

Finding	Field evidence	Survey evidence	Supported inference	Required confirmation
Sound during HVAC operation	Twelve points: 63.7-68.5 dB(A); spatial energy indicator 65.2 dB(A)	60/60 agreed with statements about consistent noise and disruption	A measured room condition and perceived concerns warrant follow-up; persistence and source are unverified	Repeated matched HVAC-on/off measurements over occupied and unoccupied periods
Duct-related path	No spectral or terminal-by-terminal measurements	59/60 identified return ducts and diffusers	Duct propagation is a candidate mechanism	One-third-octave spectra, airflow and pressure measurements at fan, duct and terminals
Vibration path	No acceleration or structural-response measurements	60/60 identified vibration transmission	Structure-borne transmission is a candidate mechanism	Acceleration and coherence measurements across source, mounts and receiving structure

Maintenance opportunity	Filter condition, fan speed and balancing state were not logged	60/60 supported filter cleaning	Inspect filter condition before deciding on maintenance	Sequential pre/post acoustic, airflow and static-pressure measurements
Receiver effect	No reverberation time or speech transmission index measurement	60/60 reported teaching and learning disruption	Communication effects require direct assessment of laboratory users	Reverberation time, speech transmission index and student and teacher assessments

Mitigation sequence and verification

The suggested sequence starts with a measured baseline. A subsequent investigation should involve the use of an integrating sound-level meter of an accepted accuracy class which is subject to traceable calibration tests and whose reading settings are documented. Fixed readings should be taken in conditions with HVAC switched on and off, including time, and one-third-octave frequency spectra. Airflow, fan operation, room occupancy, and other parameters should be obtained from the data collected. The comparison with switch-off situations suggests the regulation of external sound emissions and internal changes. Studies on sound sensing and spatial evaluation show that measuring at a single level is not enough (Fiorini et al., 2023; Grigg et al., 2021).

Every stage involves a decision point and requires baseline data that can be replicated to separate any intervention impacts from variability in operation. Assessment of maintenance outcomes is essential prior to entering a capital work phase. Any duct work or structural changes need to be based on a mechanism validated using diagnostic measurements. It is usually preferable to introduce one change at a time in order to determine its influence more readily than if all changes are carried out at once. The suggested sequence and requirements for verification are summarized in Table 4.

Table 4. Evidence-led mitigation and verification plan

Priority	**Action**	**Verification requirement**	**Decision caution**
1	Controlled baseline and diagnostic logging	Matched HVAC on/off levels, spectra, airflow, fan speed and occupancy	Do not compare unmatched operating states
2	Inspect filters, fan, belts and bearings; service or balance as indicated	Repeat acoustic and airflow measurements after each action	Avoid attributing change to multiple simultaneous actions
3	Inspect mounts, connectors and structural contacts	Vibration measurements at source, mount and receiving structure	Select isolators for actual load and forcing frequency
4	Evaluate liner, silencer or return-path redesign	Insertion loss, pressure drop, airflow, indoor air quality and fan energy	Acoustic gain must not create an energy or hygiene penalty

5	Consider room absorption if reverberation testing justifies it	Reverberation time and speech transmission index before/after	Receiver treatment will not remove duct-borne or structure-borne noise

An acceptable intervention should reduce the relevant sound or improve speech conditions while maintaining required ventilation and indoor air quality. Multi-domain studies provide a reason to assess these outcomes together (Deng et al., 2023; Pellegatti, Visentin, Torresin, Babich, Wargocki, et al., 2026). If occupational exposure is a separate concern, it requires an appropriate task-based or personal assessment rather than inference from this spatial indicator (Torres-Cobo et al., 2025).

Facilities Management Implementation

Acoustic assessment is capable of assisting the regular management of teaching laboratories as it links complaints, operating conditions, and remedial measures. This study, however, did not account for ventilation performance, energy consumption, and learning results. Hence, any benefit in these areas is a target for evaluation rather than a proven outcome. The researches on acoustics on the campus demonstrate the potential of room assessment (Mealings et al., 2024), while in this case an additional and conditional diagnosis sequence is suggested based on limited available data about the laboratory.

Anbari Moghadam and Besiktepe (2025) analyzed various applications of multi-criteria decision analysis in facilities management and building maintenance. They found uncertainty, subjectivity and the choice of technique are among the obstacles. In this laboratory, therefore, acoustic interventions need to be compared in terms of operation and maintenance criteria after diagnostic information has been collected. We did not allocate any weights to the criteria nor used any multi-criteria ranking method, since the relevant performance and cost data was not available at this time.

The order of events favours the inspection and maintenance of equipment prior to any modification that involves heavy use of materials. For example, servicing of filters, inspection and adjustment of the fans, and air distribution adjustments may assist in solving a problem in operation. However, it needs to be checked for acoustic and energy effects. If it is decided to do the lining or install a sound silencer, selection must be made upon attenuation at the frequency required while ensuring characteristics of pressure drop, easiness of cleaning, fireproof properties, and easy access to maintenance..

A useful maintenance record must connect the initial complaint or assessment trigger to the routine check figures, condition of the equipment, intervention taken, and the outcome of maintenance measures. Wherever applicable, records regarding costs and operation should be kept. The team will be able to stop working when the result of maintenance is satisfactory or prove the need for changes in design if the problem has not been completely resolved. The importance of keeping operational data is supported by facilities management studies (Omar et al., 2024).

The ongoing worries surrounding HVAC system and air passageways support Amirul's previous research in UTHM Pagoh, which was mentioned by Awang et al. (2019). However, the concurrence of findings in the six expert interviews used in that study and the responses of personnel used in this study is not a proof for the physical noise phenomenon. The previous survey was conducted by using five minute observations in ten labs, whereas this study used two minute observations at 12 locations in a single lab. All of these discrepancies, together with the absence of the measurement data, make it impossible to draw a valid conclusion that improvement or deterioration took place in the process of time.

Urbanised settings rely heavily on the collaboration of numerous facility experts to assess communication conditions. In this case, the facility manager should take charge of the assessment and maintenance records, while the HVAC contractor would deal with maintenance and operating developments. The acoustics expert would be needed to determine the measurement protocol and acceptance criteria, similar to students and professors who would need to play a role in assessing the communication environment. Here, it is important to note that the listed roles are only suggested and are not evaluated in the research. The coordination of the

proposed framework fits into the framework of the overall competency inventory in facilities management described in recent studies (Awang et al., 2014).

The management process suggested clarifies the uncertainty that still remains and connects it to measurements in the future. However, financial savings and acoustic certification as well as improvement of education are not demonstrated. The assessment of usefulness and transferability of this new method can be carried out through implementation and testing in this or other laboratories.

Limitations and Research Validity

This study includes one laboratory study, one field study, and a purposely selected sample of personnel. Microphone coordinates and height, equipment settings, time evolutions, spectra, airspeed and vibration were not reported, while a simple laboratory layout, presented in Figure 1, does not show measurement sites. Occupancy descriptions stated in the report differ depending on the project, while only few information about other equipment loads is available. Despite the claim about pre-testing calibration there are not records from that time. The certificate available (from May 5, 2026) has been issued after the experiment, only applies for 94 dB and 114 dB at 1 kHz, and shows corrections of -0.5 dB and -0.7 dB which were not implemented so far that resulted in instrument uncertainty being unknown at the stated levels. Moreover, there is no information provided about extraction procedure used. All these factors limit measurement comparison and do not allow to attribute the observed levels totally to the HVAC itself.

The project was not able to conduct repeated measurements on weeks and seasons since the project schedule did not allow it, nor was it possible to control external factors such as ambient temperature, occupancy and equipment load. Acoustic simulation was also planned but could not be carried out due to software licensing and installation issues, and thus the field data were not supported by simulation results. The results of the questionnaire could have been influenced, especially since the majority of respondents were from a single organisation and that there was a wide range of jobs represented in the sample. The possibility of purposive sampling, organisational bias and/or common-method bias cannot be ruled out and the personnel perceptions were not checked using independent instruments. The final version of the items used as well as the missing-data pattern did not provide enough information to conduct an aggregate analysis of the scale.

The spatial energy indicator has a descriptive nature and cannot be considered as a value of personal exposure, compliance criterion for rooms or time average. There is no confidence interval given, since fixed positions were not a random sample, while repeatability was not evaluated. Pilot alpha applies only to the draft questionnaire; the reliability and validity of the final groupings of items have not been proven. Experimental research in the field of sound study and cognitive performance motivate a certain straightforward judgment about the effects produced. however, evidence needed in this case is not provided.

CONCLUSIONS

A preliminary analysis of the noise levels coming from the HVAC system was done in the lab, which measures 63.7 to 68.5 dB(A) at 12 locations. The average noise level was 65.0 dB(A) while it was 65.2 dB(A) based on the energy-weighted measuring system. The views of the employees regarding the nuisance caused by the system and the possibility of duct and vibration paths were similar. However, since there is no comparison with measurements taken with the HVAC unit switched off and no site-specific measurements were done, the responses serve merely to identify possible problems without proving their nature and consequences.

We suggest a multi-step approach that starts with an acoustic test under controlled conditions and inspection of equipment, and continues to condition-based maintenance. Vibration treatment, duct or room treatment will take place only when diagnostic evidence suggests that relevant mechanism is present. This work makes clear connection between screening evidence and measurements needed for making interventions. No attenuation, energy saving nor improvement in learning was proved.

Subsequent investigations must leverage identical operating conditions, properly calibrated instruments and frequency dependent spectral data combined with airflow and structural vibration data using thorough

instrument and environmental metadata. Only one intervention should be applied at a time with impact analysis at the designated positions as well as comparing results against pre-set acoustic and ventilation criteria, accounting for attenuation, energy consumption and indoor air quality associated with each stage. Staff perception is to be validated through evaluations by independent parties of student and teacher task performance and speech transmission indices allowing assessment of speech conditions and educational relevance with respect to the intervention.

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Author Contributions

All authors contributed to the conception of the study, data collection or interpretation, manuscript preparation and critical revision. All authors reviewed and approved the final manuscript.

Declaration of Generative AI Use

During preparation of this manuscript, the authors used ChatGPT (OpenAI) to assist with drafting and language revision, organisation, reference checks and descriptive calculations from the reported data. No empirical observations or participant responses were generated by the tool. The authors are responsible for critically reviewing and verifying the final text, calculations and references before submission.

Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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