The Interrelationship Between Room Acoustics Parameters as Measured in University Classrooms Using Four Source Configurations

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This paper investigates the interrelation of room acoustics parameters as measured in lecture theatres/classrooms using four sound source configurations. Ten typical rooms were selected as representative of university premises and measured to ISO 3382 standards. The study focuses initially on the type of sound source used, to establish the suitability of multi source based measurements in assessing the acoustics of classrooms. Acoustic performance is then discussed in the context of the relationship between room acoustics parameters with and without significant background noise, with a particular focus on speech intelligibility. To facilitate a more efficient discernment of results, EDT, T30, Clarity indices and MTI were considered, as they are commonly included in general room acoustics assessments. Either of the source configurations was found to be suitable for performing general purpose measurements in (small) rooms. Clarity and EDT were found to be linearly related to the modulation transfer index in noiseless conditions, in line with earlier findings, thus an excellent predictor of STI. Background noise could be ascertained as of primary importance in the case of a non linear relation.

1. INTRODUCTION

Room acoustics of classrooms and lecture theatres has been extensively investigated [1, 2, 3, 4, 5, 6]. Objectives of these investigations ranged from defining optimum RT's within classrooms to prospective interrelations of acoustic parameters that are typically used in describing acoustic conditions, in particular speech intelligibility. Building on this research, the performance of a multi source sound system as an alternative to the traditional omni directional source type in room acoustics measurements is examined in this paper. The potential advantage is in practicalities e.g. no setup time or access to spaces otherwise unavailable for testing, as the effect of such a configuration on general acoustic parameters e.g. RT has not been specifically addressed in comparison to standard measurements using a single omni directional sound source.

The study is based on the room acoustics measurements for a combination of ten lecture rooms that are considered typical within university premises; the latter comprising building stock, as found within London South Bank University, sharing for the most part characteristics such as a rectangular shape, hard (reflecting) walls in the room perimeter and primarily a small volume with low overall RT. The measurement methodology is described in detail for the experimental conditions and results are analyzed in terms of the type of source to determine the level of usability for a consistent room acoustics assessment. Acoustic performance is then discussed in the context of the relationship between various parameters, with a particular focus on speech intelligibility under noiseless and noisy conditions.

2. SPEECH INTELLIGIBILITY MEASURE INTERRELATIONS

The interrelation between measures of

speech intelligibility and their individual relation to STI has been extensively studied in the literature. These investigations revolved around mathematical relations, to enable inter-comparison and/or discernment of results, and to establish the potential correlation to speech intelligibility.

Bradley [1, 2] and Bistafa [3] have studied these interrelations for a range of conditions and established a mathematical connection in a number of cases. Most notably, the C_{50} ratio has been found to be linearly related to STI for simulated controlled natural acoustics conditions, incorporating negligible background noise [1]. This work has further defined a just noticeable difference (JND) relating to the subjective perception of level changes to a sound field.

For small rooms, such as classrooms, using either a 50 ms or 80 ms time limit for defining early energy can be expected to result in similar trends when compared to STI [2]. Thus, implying that for speech applications an efficient assessment can be made using either limit. It was established by Bradley [5] that EDT and measures using the 50 ms limit (as opposed to 80 ms) could accurately (within ± 1 dB) be predicted from the reverberation time in small rooms. This outcome was supported by Mapp [4] for rooms with short reverberation times under sound system assisted conditions. In the context of the current study, the impact of the latter is that either RT or EDT could be used to describe a (small) room.

3. EXPERIMENTAL METHODS

3.1. TEST ROOMS

The range of test rooms considered in this study consisted of fitted lecture theatres and classrooms, typically found within university premises. The majority of the rooms can be described as small to medium sized spaces, with two larger rooms also included in the analysis, see table 1.

3.2. MEASUREMENT INSTRUMENTATION

Background noise measurements were taken using a Norsonic 140 sound level meter calibrated using a B & K Type 4230 calibrator. For the room acoustics measurements a Dell Latitude PC D610 fitted with a Digigram VXpocket v2 PCMCIA sound card was used. This was routed through an Audio SR707 power amplifier to a Rion dodecahedron loudspeaker. For the multi-source configurations an audio splitter (1 in, 4 out) and two or four active Yamaha HS50M studio monitor loudspeakers on tripod stands were used. Impulse responses were recorded using an Earthworks M30BX omni directional measurement microphone.

3.3. MEASUREMENT METHODOLOGY

The room acoustics measurements aimed at a general assessment of the spaces considered, enabling nonetheless

Table 1: Classrooms and lecture rooms used in the study

Room	Capacity (seating)	Volume (m^3)	Size category
Room 1	30	138	Small
Room 2	30	156	Small
Room 3	50	260	Small
Room 4	30	148	Small
Room 5	40	218	Small
Room 6	80	242	Medium
Room 7	140	250	Medium
Room 8	110	267	Medium
Room 9	62	356	Large
Room 10	240	753	Large

further post processing where necessary, as for example accounting for absolute speech and background noise levels. Natural acoustics were assessed with the use of a dodecahedron (omni directional) loudspeaker, while the sound system assisted conditions were based on a portable sound system set up (SS) common in all rooms in order to eliminate inconsistencies due to different system characteristics. Both source types approximated a flat frequency response while the directivity pattern and aiming of the distributed system were not considered at this stage. The portable sound system consisted of a combination of two or four monitor loudspeakers, positioned respectively at the two front or main four corners of the audience area. Overall, a total of four source configurations were used: two omni directional source positions (S1, S2) and two sound system formations (SS2, SS4).

Room acoustics measurements were based on the WinMLS 2004 [7] platform and a combination of a sound source (single omni directional or distributed configuration) with an omni directional receiver. The receiver positions and omni directional source positions were set at a height of 1.1 m–1.2 m and 1.7–1.8 m, respectively. Positioning of the distributed system in terms of height depended largely on the distance from the ceiling in each case, given an angled audience area for a number of rooms; a height setting in the range of 1.8 m–2.35 m was used, as appropriate. More information on the measurement setup can be found in [8].

A 10 second exponentially swept sine was used to take multiple impulse response measurements in line with BS ISO 3382-2: 2008 [9]. Divergence from the standard procedure was necessary for a number of receiver positions due to the relative position of reflective surfaces i.e. desks. The aim of this variation was to assess a more realistic environment; however, alternative positioning was chosen were possible. Samples of unoccupied background noise levels ($L_{Aeq,\ 1min}$) were recorded throughout the sessions, typically 5 samples in every room for each 4 hour measurement session.

4. RESULTS AND DISCUSSION

Measurement results are presented for the different analysis approaches of the study. In view of the base condition, the use of four sound source configurations and the acoustic parameter interrelationships are discussed.

4.1. BASE MEASUREMENTS

Table 2 presents the averaged background noise levels over the ten test rooms. The overall linear and A-weighted levels varied from 39.7 dB–57.8 dB and 34.1 dB_A–48.4 dB_A, respectively, a number of rooms having at times increased exposure to low frequency noise, as also supported by the large 125 Hz octave band standard deviation.

A statistical summary of the results for each of the test rooms and the average T_{30}, EDT, C_{50}, C_{80}, D_{50}, T_s, MTI and STI values are given in table 3 to establish the general character of the rooms considered. T_{30} as such varied from 0.49–0.92 while EDT was measured within the range of 0.42–0.81. STI varied from 0.66–0.79 with an average of 0.74, translating to a prospective 'good' speech intelligibility rating for all rooms.

Table 2: Averaged unoccupied background noise levels over ten rooms ($L_{eq,\ 1min}$) with standard deviations

Frequency (Hz)	125	250	500	1000	2000	4000	8000	Overall level
Linear	37.3	34.8	34.1	33.9	32.6	27.8	24.1	**42.1 dB**
A-weighted	21.2	26.2	30.9	33.9	33.8	28.8	23.0	**38.8 dBA**
σ	9.9	5.6	4.3	4.3	3.9	5.2	6.7	

Table 3: Acoustic parameters measured in ten test rooms (broadband average over receiver positions and source configurations) and statistical summary

Room	1	2	3	4	5	6	7	8	9	10	Min	Average	Max	STD
EDT (s)	0.45	0.49	0.42	0.81	0.73	0.53	0.54	0.50	0.71	0.45	0.42	0.56	0.81	0.14
T30 (s)	0.50	0.56	0.49	0.85	0.89	0.56	0.62	0.59	0.92	0.56	0.49	0.65	0.92	0.17
T_s (ms)	31.6	34.6	38.4	58.8	51.7	38.2	47.1	40.3	51.6	32.0	31.6	42.4	58.8	9.34
C_{50} (dB)	6.5	6.0	5.7	1.8	3.6	4.9	3.7	5.1	3.5	7.0	1.8	4.8	7.0	1.61
C_{80} (dB)	11.3	10.1	10.8	5.5	7.1	8.8	8.0	9.4	6.8	11.2	5.5	8.9	11.3	2.01
D_{50} (%)	80.9	79.7	77.0	65.2	68.1	76.3	68.1	73.7	67.8	81.3	65.2	73.8	81.3	6.09
MTI	0.77	0.75	0.79	0.65	0.69	0.74	0.74	0.76	0.70	0.77	0.65	0.74	0.79	0.042
STI	0.77	0.75	0.79	0.66	0.70	0.74	0.74	0.76	0.70	0.78	0.66	0.74	0.79	0.041

4.2. EFFECT OF SOURCE TYPE ON BASE MEASUREMENTS (DATA COMPARISON)

Results were compared in terms of reverberation times to establish the effect of the source type on the room response and assess the feasibility of substituting source types with alternatives when necessary, or simply when more practical to do so (also see [10,11]). Considering the measured data it can be deduced that the majority of the test rooms produced a primarily diffuse sound field for the higher frequency range, with the partial exception of room 10.

Table 4 shows the standard deviation for the T_{30} and EDT variation among the four source configurations as an average over all receiver positions in a room. For comparison purposes, the standard deviations are also interpreted as an equivalent percentage (%) relating in each case to the mean value at the particular data point.

Low standard deviations were established for the T_{30} case over all rooms with values well below 5% error for the majority of the experimental data. A notable exception can be seen at higher frequencies in room 10 where errors reached 23% at 8 kHz. However, with the latter room being the largest in the investigation, a quasi diffuse sound field was considered responsible for the discrepancies observed, differentiating in character from typical lecture rooms.

In the EDT case, larger differences were found given the different source configurations and related positioning within the room. Averaged results in table 4 suggest that a reasonably accurate assessment can be made with an error margin below 10% (for larger rooms an EDT JND of 5% has been defined in ISO 3382-1:2009 [12]). The smaller rooms in the investigation gave confidence in the data consistency, supporting analogous examinations (further room design characteristics can be found in [8]).

Accordingly, a room assessment on the basis of T_{30} and EDT can be performed using either of the source types to characterize a room on general performance, considering when necessary the related error margins. For computer modelling purposes where measurement results are used at a post processing stage, e.g. for model calibration, the output via either of the source configurations is further directly applicable in this respect, facilitating consistency in computer simulations for the prediction of speech intelligibility parameters. Considering a direct assessment within the rooms, the design approach should nonetheless be further addressed to account for particular characteristics, such as the provision for early reflections or BGNL variance, which could significantly affect intelligibility values for particular positions within the rooms.

4.3. PARAMETER INTERRELATIONS

Measured room acoustics parameters for the ten rooms were analysed to address

Table 4: Standard deviation for T_{30} and EDT among the four source types in Rooms 1–10 (over all receivers)

Octave band	125	250	500	1000	2000	4000	8000	
EDT s	0.069	0.052	0.022	0.019	0.019	0.011	0.021	Room 1
T_{30} s	0.055	0.02	0.02	0.006	0.006	0.006	0.041	
% EDT	**11.7**	**9.3**	**5.6**	**4.8**	**4.2**	**2.6**	**6.2**	
% T_{30}	**7.7**	**3.5**	**4.7**	**1.5**	**1.3**	**1.3**	**10.3**	
EDT s	0.087	0.041	0.027	0.029	0.013	0.022	0.045	Room 2
T_{30} s	0.071	0.044	0.014	0.002	0.003	0.008	0.047	
% EDT	**12.8**	**7.0**	**6.3**	**7.2**	**2.8**	**4.8**	**11.8**	
% T_{30}	**8.7**	**7.1**	**3.0**	**0.4**	**0.6**	**1.5**	**9.9**	
EDT s	0.046	0.024	0.051	0.027	0.018	0.022	0.021	Room 3
T_{30} s	0.068	0.007	0.009	0.023	0.032	0.038	0.008	
% EDT	**7.8**	**4.8**	**13.1**	**7.4**	**4.1**	**5.7**	**7.0**	
% T_{30}	**11.5**	**1.3**	**2.2**	**5.1**	**5.6**	**7.6**	**2.2**	
EDT s	0.258	0.053	0.042	0.038	0.019	0.008	0.062	Room 4
T_{30} s	0.293	0.157	0.028	0.011	0.009	0.014	0.029	
% EDT	**26.6**	**4.6**	**4.2**	**5.0**	**2.9**	**1.2**	**11.9**	
% T_{30}	**33.8**	**14.0**	**2.8**	**1.3**	**1.2**	**1.9**	**4.9**	
EDT s	0.179	0.081	0.039	0.016	0.056	0.042	0.059	Room 5
T_{30} s	0.107	0.048	0.019	0.006	0.008	0.01	0.049	
% EDT	**12.2**	**9.0**	**6.5**	**3.0**	**10.3**	**7.7**	**12.2**	
% T_{30}	**5.9**	**4.5**	**2.9**	**1.0**	**1.2**	**1.4**	**7.1**	
EDT s	0.052	0.061	0.017	0.026	0.012	0.052	0.025	Room 6
T_{30} s	0.028	0.072	0.013	0.01	0.02	0.065	0.055	
% EDT	**7.7**	**9.5**	**3.3**	**5.7**	**2.2**	**10.1**	**6.3**	
% T_{30}	**4.8**	**11.1**	**2.5**	**2.0**	**3.3**	**10.8**	**11.3**	
EDT s	0.093	0.044	0.053	0.03	0.033	0.048	0.047	Room 7
T_{30} s	0.067	0.021	0.007	0.01	0.007	0.012	0.026	
% EDT	**14.8**	**7.3**	**9.9**	**6.0**	**6.2**	**8.6**	**10.7**	
% T_{30}	**7.3**	**3.3**	**1.3**	**1.9**	**1.2**	**2.0**	**5.2**	
EDT s	0.109	0.083	0.038	0.042	0.042	0.046	0.06	Room 8
T_{30} s	0.089	0.023	0.003	0.009	0.02	0.007	0.035	
% EDT	**17.0**	**15.4**	**7.6**	**9.1**	**8.6**	**9.4**	**16.5**	
% T_{30}	**10.1**	**3.6**	**0.6**	**1.7**	**3.4**	**1.3**	**8.2**	
EDT s	0.073	0.031	0.044	0.04	0.108	0.233	0.089	Room 9
T_{30} s	0.035	0.014	0.018	0.012	0.007	0.007	0.05	
% EDT	**7.2**	**3.7**	**7.4**	**6.8**	**15.3**	**30.6**	**19.1**	
% T_{30}	**3.1**	**1.5**	**2.8**	**1.5**	**0.7**	**0.7**	**5.9**	
EDT s	0.056	0.036	0.019	0.024	0.045	0.08	0.082	Room 10
T_{30} s	0.031	0.032	0.001	0.003	0.037	0.098	0.107	
% EDT	**11.5**	**6.4**	**3.6**	**5.2**	**10.4**	**20.6**	**25.6**	
% T_{30}	**4.9**	**5.3**	**0.2**	**0.6**	**6.5**	**16.7**	**22.9**	

their prospective interrelationships. Considering speech intelligibility parameters in particular, it is noted that different elements of the acoustic conditions are used to attain a result. For example, clarity energy ratios make use of the room effect on acoustic behaviour while ignoring background noise, effectively the S/N. In contrast, parameters such as the STI comprise a more elaborate approach in an attempt to account for all the variables that affect acoustic performance. The conditions present in a space during a measuring session will thus unavoidably affect the output in different ways for different measures. As such, care needs to be taken when comparing dissimilar parameters or making an assumptive assessment, based on a particular methodology.

4.3.1. Discerning a comparison of Clarity (Cx) energy ratios versus MTI

STI comprises a measure describing speech intelligibility using a single number for seven octave bands, subsequently corresponding to more than a single Clarity value. In order to enable a comparison in octave band level detail, the modulation transfer index (MTI) is considered as the equivalent octave band 'STI', nonetheless the benefit of octave band weighting and redundancy corrections is not considered and therefore results could underestimate the potential relationship. In utilizing the relation between the C_x energy ratios and STI it should be reminded that the former does not account for the influence of background noise. Thus, the particular interrelation is subject to change in every environment, depending on the noise character. It is worth noting that while U_x is a measure that can be used as an alternative to C_x (in order to account for S/N), clarity is commonly used to quantify general acoustic quality in rooms. For this reason, its design and specific purpose is often overlooked, with comparisons likely to take place without regard to any limitations. A comparison of fundamentally different measures on this basis can be constructively utilized to discern the acoustic conditions.

Figure 1 shows the relation of C_{50} and C_{80} to MTI for two conditions, with and without background noise. For noiseless conditions the relation of the two measures was approximately linear, agreeing with earlier results by Bradley [1], while C_{80} appeared to be better related to MTI. The associated correlation coefficients were nonetheless comparable with values of 0.91 and 0.96, respectively for the pairs C_{50}-MTI and C_{80}-MTI, see figure $1_{(I\text{-}II)}$, with analogous performance for all four source configurations. In the conditions accounting for background noise the particular associations break down, as the measures compared are effectively modified into two fundamentally different measures. Considering that the particular relation, see figure $1_{(III\text{-}IV)}$ could be altered even within the same room under different noise conditions, a comparison of C to STI when accounting for background noise would appear as of minor significance unless some level of consistency in the noise character can be achieved.

When the S/N is high enough to render the effect of BGNL negligible in a practical application, it would be possible to predict the speech intelligibility in terms of STI from the C_{50} or C_{80} datasets with a high level of accuracy, see [2]. Therefore, for a high signal level condition C_x might also be used as a direct descriptor of speech intelligibility.

This relationship would be invalidated to a large extent when considering marginal conditions and thus could be used, if established, to ascertain BGNL as a significant factor in the acoustical conditions.

4.3.2. Room reverberance (EDT, T_{30}) versus STI

The relation of room reverberance to STI followed a similar trend as regards the effect of background noise.

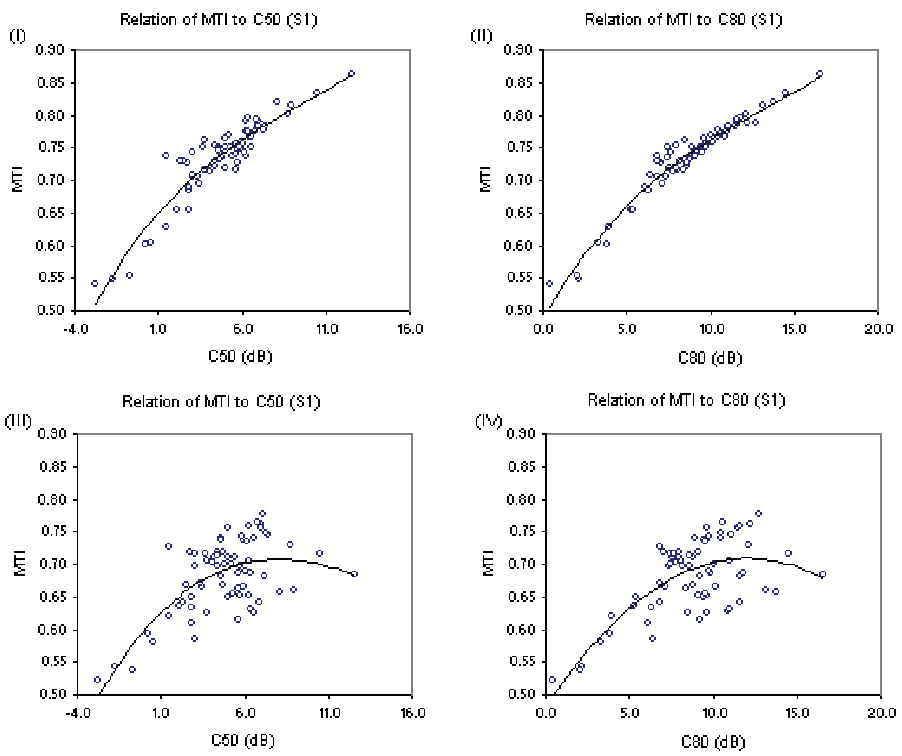

Figure 1. *Relation of C_x to MTI in ten test rooms (all data points, S1), **I**) C_{50} to MTI without background noise, **II**) C_{80} to MTI without background noise, **III**) C_{50} to MTI with background noise, **IV**) C_{80} to MTI with background noise.*

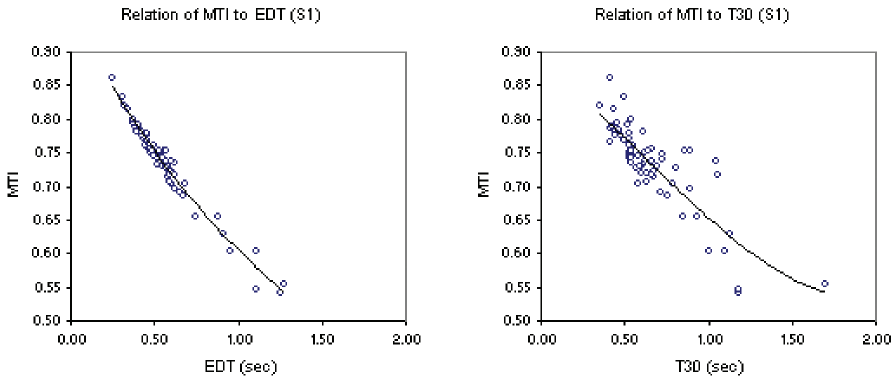

Figure 2. *MTI relation to space reverberance in ten test rooms (no noise) for S1.*

Considering EDT and T_{30}, an evident relation of reverberance to the MTI was found for noiseless (or adequate S/N) conditions, see figure 2, comparable to steady state BGNL conditions. EDT was more closely related to MTI with a correlation coefficient of 0.98 (0.85 for T_{30}) having a near linear relationship, particularly for shorter reverberation times. A similar degree of agreement was further found for all four source configurations. The relationship between the measures became less evident with the incorporation of background noise for all experimental setups (e.g. correlation coefficient 0.67 for both reverberation indices with S1). The resulting relationship would again be subject to the character of noise, being the only altered variable between the two conditions.

Accordingly, for adequate S/N, a general speech intelligibility evaluation of reasonable accuracy could be made in

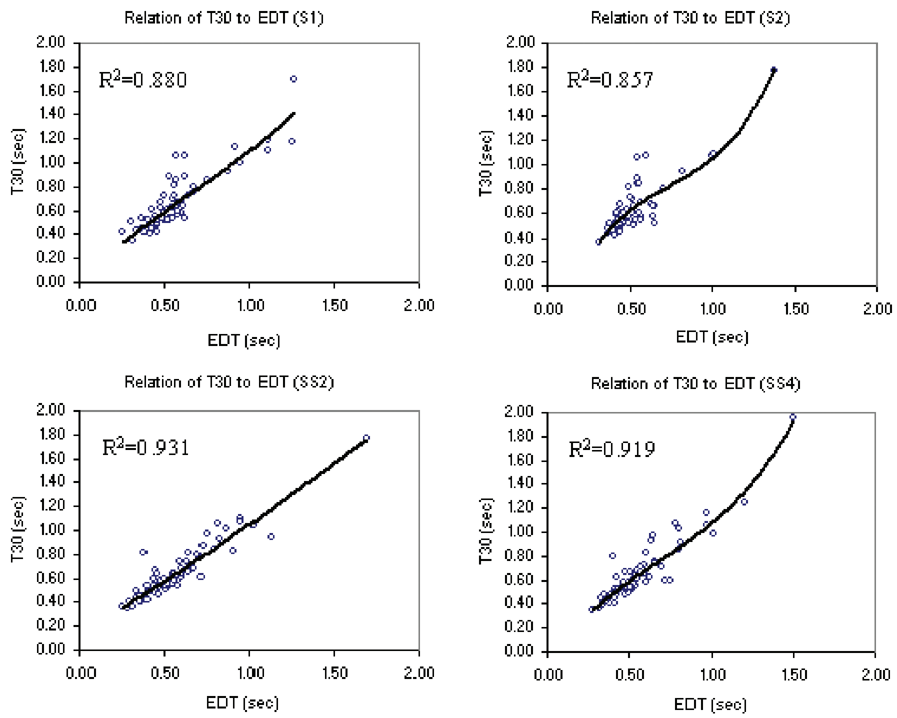

Figure 3. Relation of EDT to T_{30} for four source configurations in ten test rooms (S1, S2, SS2, SS4).

typical classrooms based on RT (primarily EDT) alone.

4.3.3. EDT versus T30

The results for T_{30} and EDT value interrelations partially supported the findings of earlier studies [5]. T_{30} could not be unconditionally used as a baseline to predict EDT and C_{50}, among other measures, within university classrooms and lecture theatres. However, considering alternate source configurations appeared to influence the T_{30}-EDT relationship producing, on a relative basis, a better defined trend. Figure 3 illustrates the closer connection between the reverberation indices when the multi-source sound system is used, particularly in the SS2 case. While all four configurations produced a relatively small deviation in terms of the correlation between parameters, it should be noted that excluding the two larger rooms of the study (rooms 9–10) from the statistical analysis resulted in a closer association for all conditions, primarily enhanced for the single source case, see figure 4. Accordingly, results suggest better uniformity among the different conditions with added confidence when assessing smaller sized rooms.

5. CONCLUSIONS

This investigation has considered ten test rooms covering a range of acoustic conditions found within typical university classrooms. For a consistent room assessment in terms of T_{30}, either of the four source configurations in test could be used. Larger differences were found for EDT between source types, given the relative source-receiver positioning in each case. Averaged values over the measuring positions suggested the feasibility of a reasonably accurate assessment on this basis. Smaller sized rooms enhanced confidence in the assessment method.

Good correlation was established between Clarity and STI (0.91 and 0.96, for C_{50} and C_{80} respectively) for noiseless or adequate S/N measurement conditions, with analogous outcomes for all four source configurations.

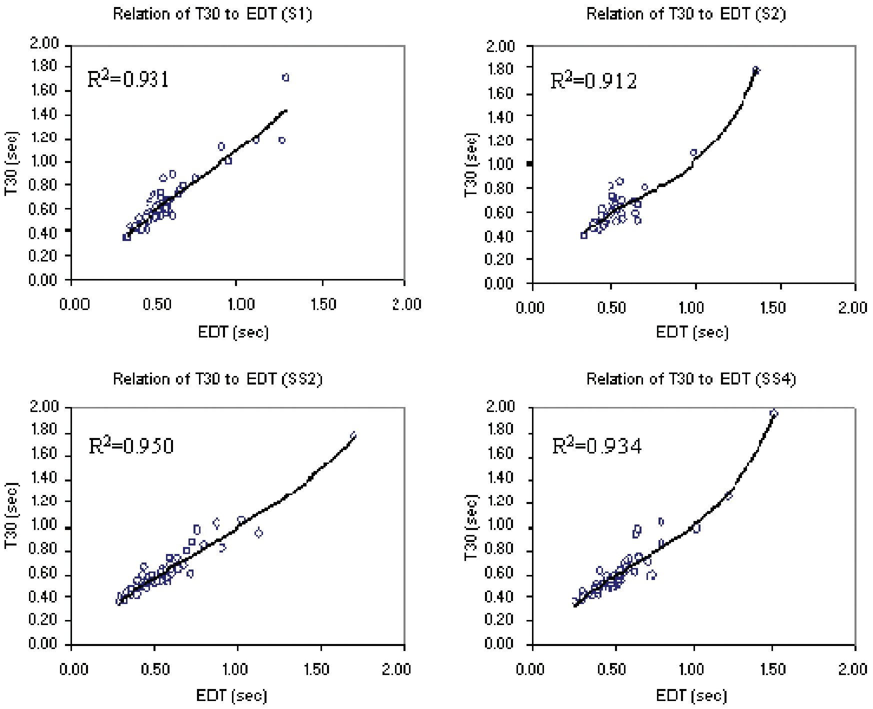

Figure 4. Relation of EDT to T_{30} for four source configurations after excluding larger rooms (S1, S2, SS2, SS4).

Speech intelligibility in terms of STI can thus be predicted with confidence from clarity datasets under these conditions, marginally more relevant for the C_{80} case. Accordingly, for high S/N in an actual case, clarity ratios can be used as a direct descriptor of intelligibility, in line with earlier research.

Given that the particular interrelation differentiates from 'near linear' when background noise is considerable, the latter can be identified as a significant factor in the acoustical conditions of a space in such a case and should be accounted for in the room description.

The relation between room reverberance (EDT, T_{30}) and STI, primarily for the EDT case, can be similarly discerned to attain an indication of the impact of background noise.

REFERENCES

[1] Bradley J.S., A just noticeable difference in C_{50} for speech, *Applied Acoustics* 58 (1999) p.99–108

[2] Bradley J. S., Relationships among Measures of Speech Intelligibility in Rooms, *J. Audio Eng. Soc.*, Vol. 46, No. 5, May 1998

[3] Bistafa S. R., Bradley J. S., Reverberation time and maximum background-noise level for classrooms from a comparative study of speech intelligibility metrics, *J. Acoust. Soc. Am.* 107 (2), February 2000

[4] Mapp P., Relationships between Speech Intelligibility Measures for Sound Systems, Presented at AES 112th Convention , Munich, Germany, 2002 May 10–13, Convention paper 5604

[5] Bradley J. S., Speech intelligibility studies in classrooms, *J. Acoust. Soc. Am.* 80 (3), September 1986

[6] Hodgson M., Experimental investigation of the acoustical characteristics of university classrooms, *J. Acoust. Soc. Am.* 106 (4), Pt. 1, October 1999

[7] Morset L., Morset development, WinMLS 2004, Professional Measurement Software for PC and Soundcard, User's Manual, www.winmls.com

[8] Nestoras C., *The assessment of speech intelligibility in room acoustics for efficient application in computer modelling and improved enclosed spaces*, PhD Thesis, London South Bank University, 2009

[9] BS EN ISO 3382-2: 2008, Acoustics - Measurement of room acoustic parameters - Reverberation time in ordinary rooms

[10] Nestoras C., Gomez L., Dance S., Murano S., Speech intelligibility measurements in a diffuse space using open and closed loop systems, Proceedings of the 19th International Congress on Acoustics, Madrid, 2007

[11] Gomez L., Nestoras C., Dance S., Murano S., Speech intelligibility measurements in a non-diffuse space using open and closed loop systems, Proceedings of the 19th International Congress on Acoustics, Madrid, 2007

[12] BS EN ISO 3382-1:2009, Acoustics - Measurement of room acoustic parameters, Performance spaces

RESIDENTS HIRE THEIR OWN EXPERT TO MEASURE WIND TURBINE NOISE

Residents near Macarthur, in south-west Victoria, (Australia) dispute that the town's wind farm is meeting noise requirements. The wind farm's operator, AGL, says it has been consistently meeting requirements for noise levels since the facility became fully operational in January. Annie Gardner lives next door to the wind farm and says several locals have banded together to commission independent research into the noise levels. "If the wind is blowing in your direction people say it sounds just like a truck coming in your direction and the truck just keeps on coming and never arrives, or I feel it's like a tornado, the incredible noise before a tornado comes," she said. She says about 10 neighbouring households have commissioned an acoustic expert to conduct independent research. "Just for two weeks it's probably $6,000, which none of us can afford, but you have to realise that we actually have lost our properties in this situation because no-one would want to live next to the wind farm, particularly when they know how badly it's affecting our health," she said.

PICK YOUR FAVOURITE MONITORING COMPANY

Vermont regulators have rejected a noise complaint aimed at a Vermont industrial wind farm. First Wind operates the 16 turbine project in Sheffield. It came on line in autumn 2011 — the first modern, large-scale wind farm in Vermont. A Sutton resident complained of excessive noise from the turbines. But the Vermont Public Service Board said the project is meeting its noise standards and is in compliance with its Certificate of Public Good. The anti-wind group Vermonters for a Clean Environment is criticizing the PSB, noting that First Wind chose the company that conducted the sound monitoring.

WIND FARMS: PROPERTY PRICES PLUMMET?

Land-based wind turbines can cause property values within two miles of the structures to plummet by 15 percent to 40 percent, according to comprehensive appraisal studies. The individual real estate impact reports covered the towns of Falmouth, Nantucket, Shelburne, Dennis, and Brewster and are emblematic of similar studies in other states, according to Michael McCann , president of McCann Appraisals of Chicago. "The wind turbines near residential areas are devastating to home values," McCann said. His firm has conducted more than 20 appraisals of homes near existing or proposed land-based wind turbines in more than two dozen communities across the country.