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Significance of Speech Intelligibility Assessors in Medium Classroom Using Analytical Hierarchy Process

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Abstract

When there are constraints on the resources-equipment, manpower and time-to conduct speech intelligibility tests, the most reliable or significant SI assessor for many different types of rooms is always sought for. The purpose of this study was to determine the most significant speech intelligibility assessor in four medium classrooms. The speech intelligibility assessors tested were RT60, C50, D50, and STIPA. The data were acquired by means of sound recorder that recorded six Malay words spoken by a trained male speaker, in four medium classrooms.The recorded speech signals were analyzed by DIRAC software. The data of four speech intelligibility assessors have to be normalized before it can be analyzed by AHP. In conclusion, C50 has shown the most consistent prediction of speech intelligibility in all sampled classrooms. On the other hand, as the room gets larger, RT60 becomes significant for determining speech intelligibility in these sampled classrooms.

Keywords*: Reverberation, Speech intelligibility, Analytical hierarchy process*

1. Introduction

High level of speech intelligibility in the classroom due to room's response to speech signals is essential for optimum learning.Also, classroom with high level of speech intelligibility is able to rule out itself should defect in learning output is detected. Thus, defect in learning outputs may be due to other factors such as defect in delivery of learning materials and or loss of focus on part of the students, but not because of the classroom itself. However, insufficient acoustics consideration in classroom design may lead to poor speech intelligibility in it.

According to a survey, about one-fourths of 250 respondents had been detected with high level of depression, anxiety and stress when they attended classes in two classrooms of 320 m3 and 810 m3 respectively. The problem with these classes was their high 3 seconds reverberation time (RT60) they had [1]. This high RT60, which created late lingering reverberant speech sounds in these classrooms, had caused intelligibility of speech in the classrooms to become very poor. The optimal RT60 for these classes should be 0.6 second and 0.7 second respectively.

Several guidelines for speech intelligibility in buildings are stated in IEC 60849 [2] and IEC 60268 [3]. There are parameters such RT60, Speech Transmission Index (STI), and sound signal strength in terms of sound pressure level (SPL) that can affect level of speech intelligibility in classrooms. For educational process in general, STI should respond to syllable intelligibility higher than 95%. The authors have found out that syllable intelligibility of 95%, which was tested using logatome (or nonsense syllables) recognisability, is somewhat equivalent to STI of 0.75. Also, they have found out that SPL of 70-80 dB is required for good speech intelligibility in classrooms. However, clarity of speech output drops when SPL in the room goes above 85 dB. With such high SPL, clarity of speech drops due to reduced sensitivity of the ears [4].

In another study, definition (D50), sound strength (SPL), and RT60 had been tested in two medium room models of two different shapes-symmetry and asymmetry. By using modelling software, the recorded speech signals were convoluted with the room impulse response of each model. Subjective speech intelligibility test had been conducted by having real listeners to listen to those convoluted speech signals. From the feedbacks of questionnaires of 25 participants,

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the authors have found out that more than 80% of the participants were unable to distinguish the differences in speech intelligibility in symmetrical and asymmetrical medium rooms. However, room shapes has significant on RT60 [5].

From the findings of previous researchers, it can be inferred that speech intelligibility can be assessed using many parameters. However, in the event of limited resources, which are equipment, manpower, and time, significance speech intelligibility assessor is worthwhile to seek for. This paper presents the study on four speech intelligibility assessors, in four medium classrooms, to determine the most significant assessor. It is hypothesized that speech intelligibility assessor does not behave equally in the entire tested classrooms. Instead of using real listeners or simulation packages to evaluate the measured data, analytical hierarchy process (AHP) had been deployed for the process.

AHP is a multi-criteria (tangible and intangible) decision making analysis tool that is used to evaluate the views of the stakeholders with the aidof decision making software. AHP has been applied to numerous areas, such as in assessing sustainable municipalsol waste management factors, land mapping to determine land susceptibility to landslide, and in improving healthcare service quality. The AHP is an eigenvalue technique to the binary or pair-wise comparisons approach. It is based on three principles: decomposition, comparative judgment, and synthesis of priorities. The AHP provides a numerical fundamentalscale, which can range from 1 up to 9, to calibrate the quantitative and qualitative performances ofpriorities. The consistency of the final weight of each priority can be determined using consistency ratio (CR). If CR is less than 10%, then the matrix can be considered as having an acceptable consistency [6-9]. AHP has been used across various discipline such as assessing information security risk [10], or in the field power system generator [11] to determine the best way to plan distributed generators. AHP is also used as a tool to determine the best combination of courses to give to university students [12].

2. Research Method

The hierarchy for priorities of this study is shown in Figure 1. Speech intelligibility assessors, which are reverberation time (RT60), Clarity (C50), Definition (D50) and STI for Public Address (STIPA), were tested in four medium classrooms.

2.1. Speech signals for the study-Six Malay words

In this study, the speech signals to be played in the classrooms were six Malay words, recorded from a trained male speaker. Table 1 shows recorded Malay words with respect to their manner of articulation (MoA). Four manners of articulation were chosen in such a way to obtain distinctive phonetics of the chosen Malay words.

2.2. Data acquisition

As illustrated in Figure 2, sound source for the measurement were located at the middle of the class. The source was ensured to be placed the minimum 1 meter from the wall – as if a speaker is facing audiences in a classroom setup. The sound recorder was moved around in the classrooms to capture speech signals, at a predetermined distance from the sound source.

Except the RT60 values that were determined at site, Clarity, Definition, and STIPA values were derived from recorded played Malay word speech signals (in .wav format), in the classrooms. The analysis software DIRAC had been used to decipher the recorded speech signals in the classrooms to obtain values of Clarity, Definition, and STIPA. Chosen for illustration, Table 2 shows acquired RT60 data in the sampled classrooms.

2.3. Normalized data for evaluation using AHP

In order to prepare the data for evaluation using AHP, the authors had chosen SI assessor data at 6 meters from the sound source. This is due to the fact that at 6 meters, this listening position is free from the effect of obstructing walls in a way that spatial effects of the room of that listening position intact. Table 3 shows strategy for data normalization for each of SI assessors. RT60 of the classroom will contribute to better intelligibility when measured and optimal are the same. In logarithmic terms, difference RT60 (ΔRT60) 0 dB is sought for it is the best value for good speech intelligibility as shown in Table 4.

Clarity (C50) indicates good speech intelligibility when it is 0 dB or above. However, for this study the authors have no way of comparing acquired C50 with other C50 terms from results of the experiment. Even though, average C50 can be calculated from the measurement as shown in Table 5, it does not correlate any C50 at all for comparison.

Definition (D50) indicates good speech intelligibility when its value reaches 20% or higher. In Table 6, the authors have chosen room response for the Malay word dapat for the analysis of D50. This Malay word was chosen because it yields the most consistent D50 results in the entire sampled classrooms.

Finally, STIPA indicates better to excellent speech intelligibility when its value is closer to 1 (One). Again, the Malay word dapat gives the most consistent STIPA results. Even though the Malay word tahunalso gives consistent STIPA result, STIPA values from the word dapat was chosen to be consistent with SI assessor D50.

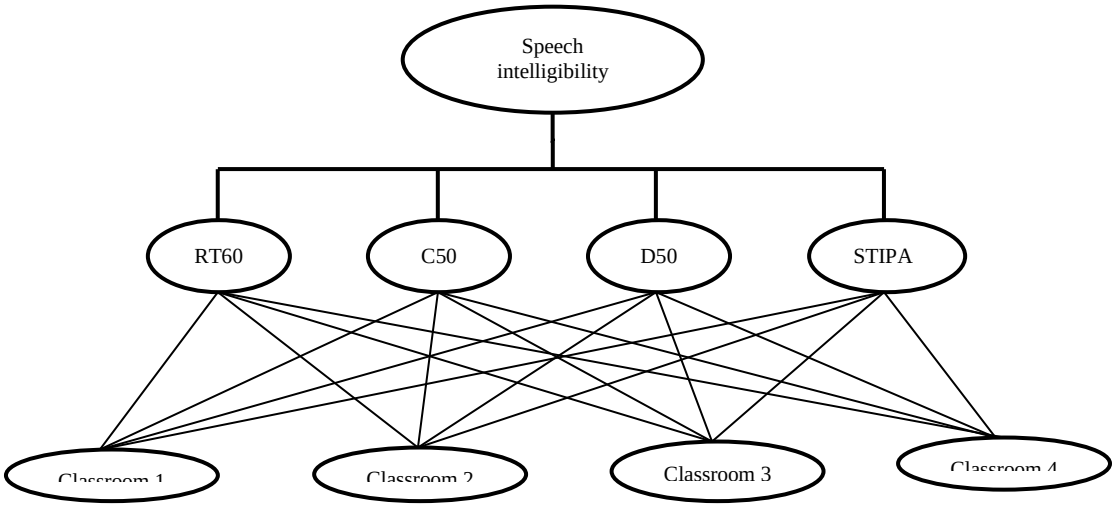

Figure 1. Analytical hierarchy process of determining significance of speech intelligibility assessors in medium classrooms

Table 1. Six Malay words for recorded for signals

Chosen MoA	Malay Words
Plosive	DAPAT
Plosive	TAHUN
Nasal	NADI
Fricative	SAYA
Vowel	AMAN
Vowel	USIA

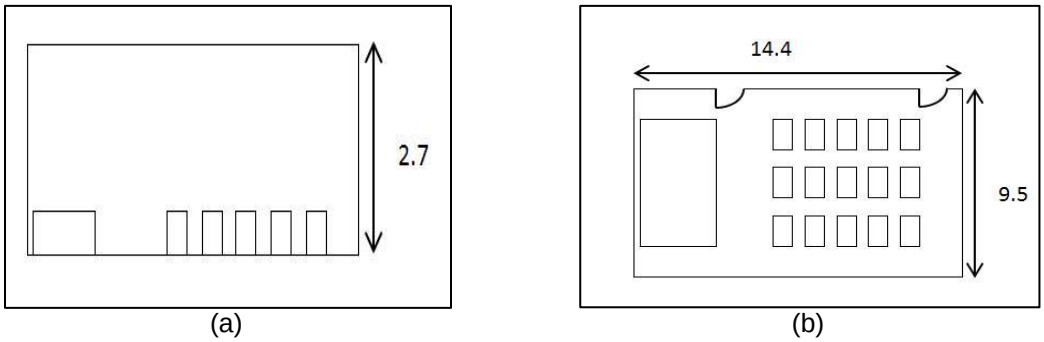

Figure 2. (a) Side view and (b) plan layout of one of sampled classrooms

Table 2. RT60 data in the sampled classrooms

Classroom	Distance (m)	Frequency (Hz)			
		250	500	1000	2000
1	1.04	1.18	1.10	1.10	1.10
	2.00	1.28	1.10	1.10	1.20
	4.00	1.41	1.16	1.09	1.13
	6.00	1.44	1.22	1.08	1.12
	Average	1.33	1.15	1.09	1.14
2	1.04	1.58	1.25	1.08	1.14
	2.00	1.45	1.10	1.06	1.10
	4.00	1.24	0.95	1.09	1.08
	6.00	1.15	0.95	1.14	1.09
	Average	1.36	1.06	1.09	1.10
3	1.04	0.44	1.58	1.63	1.36
	2.00	0.32	1.47	1.55	1.33
	4.00	0.35	1.38	1.47	1.27
	6.00	0.50	1.62	1.43	1.2
	Average	0.45	1.48	1.50	1.33
4	1.04	0.11	1.10	1.24	1.18
	2.00	0.24	1.35	1.10	1.11
	4.00	0.36	1.35	1.10	1.08
	6.00	0.26	1.54	1.28	1.39
	Average	0.23	1.35	1.10	1.16

Table 3. Strategy for normalization of data of SI assessors to prepare for evaluation using AHP

Speech intelligibility (SI) assessor	Relationship to SI (Rating/Score)
RT60	The best ΔRT60 is 0 dB. +ΔRT60 is a plus for SI; albeit the acoustics design cost for the room will be higher. $RT60 = \left[\frac{0.16V}{S\alpha}\right](s)$ $\Delta RT60 = 20.\log\left[\frac{RT60_{Measured}}{RT60_{Optimal}}\right](dB)$
C50	SI is good for C50 equals 0 dB or higher. $C50 = 10\log\left[e^{\frac{1.104}{RT60}}\right] - 1(dB)$
D50	D50 of at least 20% for good SI. $D50 = \frac{\int\int_0^{50} p^2(t)dt}{\int\int_0^{\infty} p^2(t)dt}(\%)$ $\Delta D50 = 20\log\left[\frac{D50_{Measured}}{D50_{Average}}\right](dB)$
STIPA	STIPA ranges from 0-1. Speech signal is barely intelligible (Poor) when STIPA is within 0.30 – 0.45. SI is rated Excellent, if STIPA score is within 0.75-1.0.

3. Results and Analysis

In the sampled classrooms, it is noted that measured RT60 is found to be somewhat double of its optimum value. This situation does not really show encouraging indicator of good speech intelligibility to be expected in all sampled classrooms as shown in Table 4.

In Table 5, C50 values are generally acceptable, ranging from 1 dB to 3 dB in all sampled classrooms. Moreover, C50 results in this study are consistent since the lower C50

scores were measured in larger classroom (Classroom 3 and Classroom 4). From Table 6 and Table 7, the D50 and STIPA scores from the Malay word dapat are very consistent in all sampled classrooms. Classroom 1 and Classroom 2 exhibit good D50 and STIPA scores, compared to Classroom 3 and Classroom 4.

Even though the Malay word tahun exhibit consistent scores for STIPA in the sampled classrooms, however, it was not selected for consideration because its score does not correspond well for D50. As shown in Table 7, for the Malay word tahun, except D50 score in Classroom 1, D50 scores are fine in other classrooms.

In Table 8, score 0 dB or higher for ΔRT60, C50, ΔD50 andΔSTIPA indicates good speech intelligibility. It is shown in Table 9 that this experiment has Consistency Ratio (CR) of less than 0.1. This value indicates that the judgment made in the process to determine n by n pairwise comparison matrix is valid.

Table 4. Difference RT60 (ΔRT60) in sampled classrooms

Classroom	RT60 (s)	Volume (m^3)	Optimum RT60 (s)	ΔRT60 (dB)
1	1.1	370	0.6	-5
2	1.1	370	0.6	-5
3	1.5	634	0.6	-8
4	1.1	562	0.7	-4

Table 5. Clarity (C50) in sampled classrooms

Classroom	$C50_{Design}$ (dB)	$C50_{Average}$ (dB)
1	3	2.25
2	2	2.50
3	1	0.50
4	1	1.75

Table 6. Malay word *dapat* yield the consistent D50

Classroom	Malay Words					
	Aman	*Dapat*	Nadi	Saya	Tahun	Usia
1	12	*12*	0	16	0	0
2	70	*12*	72	72	37	68
3	7	*1*	0	0	2	23
4	4	*1*	1	0	6	49

Table 7. STIPA and D50 from Malay word *dapat*

Classroom	Malay Words					
	Aman	*Dapat*	Nadi	Saya	*Tahun*	Usia
1	0.53	*0.49*	0.65	0.44	*0.58*	0.49
2	0.49	*0.47*	0.56	0.46	*0.58*	0.50
3	0.36	*0.39*	0.47	0.43	*0.44*	0.45
4	0.43	*0.38*	0.44	0.39	*0.44*	0.40

Table 8. STIPA and D50 from Malay word *dapat*

Classroom	SI assessor			
	ΔRT60 (dB)	C50 (dB)	ΔD50 (%)	ΔSTIPA
1	-5	3	-4	-6
2	-5	2	-4	-7
3	-8	1	-26	-8
4	-4	1	-26	-8

Table 9. Overall priority factor of speech intelligibility assessors in all sampled classrooms

Classroom	SI assessor				Consistency Ratio (CR)
	ΔRT60	C50	D50	STIPA	
1	0.195	0.391	0.276	0.138	0.045
2	0.195	0.391	0.276	0.138	0.045
3	0.234	0.395	0.140	0.232	0.022
4	0.276	0.391	0.138	0.195	0.045

Table 10. Ranking of speech intelligibility assessors in all sampled classrooms

Classroom	SI assessor			
	ΔRT60	C50	D50	STIPA
1	3	1	2	4
2	3	1	2	4
3	2	1	4	3
4	2	1	4	3
Average	3	1	3	4

4. Conclusion

In conclusion, C50 is the most significant speech intelligibility assessors due to its consistency of results in all sampled classrooms. In all sampled classrooms, C50 exhibits the highest priority vector in the AHP.

STIPA, however, does not show much significance in determining speech intelligibility in medium classrooms. It is may be due to the fact that STIPA was developed using nonsense syllables and it is also a Western based SI assessors that the language is generally monosyllable. On the other hand, in this study the Malay words were used in the experiment. Malay words normally are poly syllables.

As the room gets larger, RT60 has shown significance in exhibiting speech intelligibility in the medium classrooms. As tabulated in Table 10, the average rankings of SI assessors over the entire sampled classrooms are not very useful since there are two sets of almost identical volume classrooms, Classroom 1 and Classroom 2 versus Classroom 3 and Classroom 4. Again from Table 10, using Malay words as the sound source, C50 stands out as the most consistent speech intelligibility predictor in all sampled classrooms.

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