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Acoustic Characterization of Worship Ambience in Catholic Churches - Old Goa's Capela do Monte A comprehensive example

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ABSTRACT

The Acoustic Characterization of Worship Ambience, a method used in Old Goa's Capela do Monte (a significant Catholic church of Goa, a former Portuguese colony in India), introduces a new concept of describing the worship mood through evaluation of architectural acoustics results. Three acoustically constituted worship parameters named Sacred Factor (SaF), Intelligibility Factor (InF) and Silence Factor (SiF) are presented in this study. The constituent subjective acoustic measures were analyzed and averaged in four listener zones within the church. The objective acoustic parameters RASTI, RT, EDT, D_{50} , C_{80} , TS, ITDG, G, and L_{eq} were measured. All acoustic parameters were normalized using the data of previous acoustic measurements in Portuguese Churches.

SaF was found to relate with Initial Time Delay Gap (ITDG) ($R^2 = 0.99$) with a "F-Statistic" probability ($p < 0.01$). InF related with D_{50} and EDT ($R^2 = 0.99$) ($p = 0.07$) and with subjective Directionality ($R^2 = 0.95$) ($p = 0.03$). SiF showed correlation with G ($R^2 = 0.99$) ($p = 0.05$). The tested prediction equations derived from regression analysis showed the possibility of evaluating and designing a "Tranquil Worship Mood parameter" in a Church, from measured and calculated acoustic parameters.

1 INTRODUCTION

The optimal celebration of the Sacred Liturgy in a worship space requires optimized synergy between speech, music, singing and silence as proper to the liturgy of that worship space in a given architectural enclosure [1, 2]. In the constitution of Acoustic Comfort Impression (ACI) [3], Reverential Awe, Intelligibility and Silence were hypothesized as determinants of 'comfort' in a worship space. These determinants of 'comfort' had to be independently studied to assess their capacity to be coherently constituted of subjective acoustic perceptions and objective sound decay parameters. These determinants of 'comfort' would also be simultaneously needed to be theologically rich and effective. In this pruning process the experience of 'Awe' was replaced by the experience of the 'Sacred' as the latter was inclusive of 'Awe'. Consequently, it was decided that three distinct, theologically sound "Worship Parameters" be acoustically constituted and termed as the Acoustic Worship

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Indices (AWI). The three distinct AWI were named as: Sacred Factor (SaF); Intelligibility Factor (InF) and Silence Factor (SiF). This method of characterizing the ethos of worship through acoustically constituted worship categories would be termed as “The Acoustic characterization of worship ambience method”. These three derived worship parameters would be a subtle improvement over the comprehension of the ‘Tranquility Factor’ in a worship space in terms of the Acoustic Comfort Impression. In this study the results of this method in Capela do Monte are presented. This study presents some of the results of the acoustic measures and the derived acoustic parameters using the above mentioned method in Old Goa's Capela do Monte (a significant Catholic church of Goa, a former Portuguese colony in India).

2 CAPELA DO MONTE: THE SAMPLE CHURCH

2.1 Historico-Architectural Setting

This chapel, commonly called Capela do Monte, recently restored under the auspices of Fundação Oriente, earlier reconstructed more than once, was built under the orders of Afonso de Albuquerque in 1511 and referred to as in existence in 1519 [4]. The chapel in its present form was built in 1557 [5].

Infact Capela do Monte is not a Chapel, at least in European terms. This single nave Church is a mannerist Goan variant of the typical “Portuguese box like Church” [6]. The nave is covered with a coffered barrel vault. The Sanctuary (Chancel) is lower than the nave but quite deep and has the same kind of a vault. At the main entrance of the Church lies a massive upper Choir with a huge dome that supports it.

2.2 Technical Details (Architectural)

The architectural details of the Capela do Monte are shown in Table 1.

Table 1: Architectural details

ARCHITECTURAL MEASURES	DESCRIPTION	UNITS	VALUES
Total Absorption	ABS_{TOT}	m^2	92.04
Absorption Coefficient	C_{ABS}	α	0.07
Total Floor Area	A_{TOT}	m^2	250
Nave Floor Area	A_{NV}	m^2	81
Maximum Height	H_{MAX}	m	15
Maximum Nave Height	H_{NV}	m	15
Maximum Length	L_{MAX}	m	30
Nave Length	L_{NV}	m	14
Total Volume	V_{TOT}	m^3	2974
Nave Volume	V_{NV}	m^3	1753
Total Average Height	H_{AVG}	m	12
Maximum Nave Width	W_{NV}	m	9
Average Width	W_{AVG}	m	7
Minimum Nave Width	W_{MIN_NAVE}	m	9.2
WIDTH Average NAVE	W_{AVG_NAVE}	m	9.2
Minimum Nave Height	H_{MIN_NAVE}	m	10
HEIGHT Average NAVE	H_{AVG_NAVE}	m	12.3

The ground floor plan of the church shown in Figure 1 reveals the diminished sanctuary style of the church.

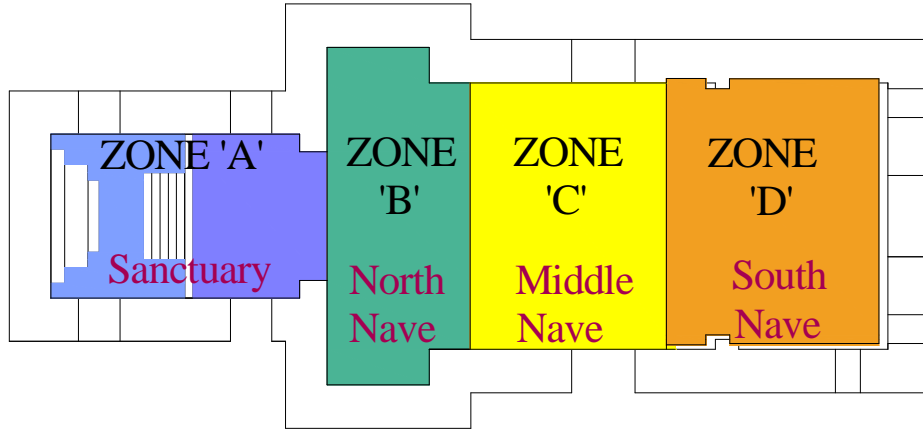


Figure 1: Ground Floor Plan with the zones demarcation (Floor plan courtesy: Engr.Thomas D’Costa)

3 METHODOLOGY AND TERMINOLOGY

3.1 Listeners and Music-Speech sources

Nineteen trained normal listeners were spatially seated into four seating zones within the church. The contemporary choir location in the nave (Ground floor) and the choir loft location (First floor) of the church were chosen as Music Source positions ‘MA’ and ‘MB’ respectively. The altar and the pulpit locations were chosen as Speech Source positions ‘SA’ and ‘SB’ respectively.

The Source and the Listener locations are shown in Figure 2.

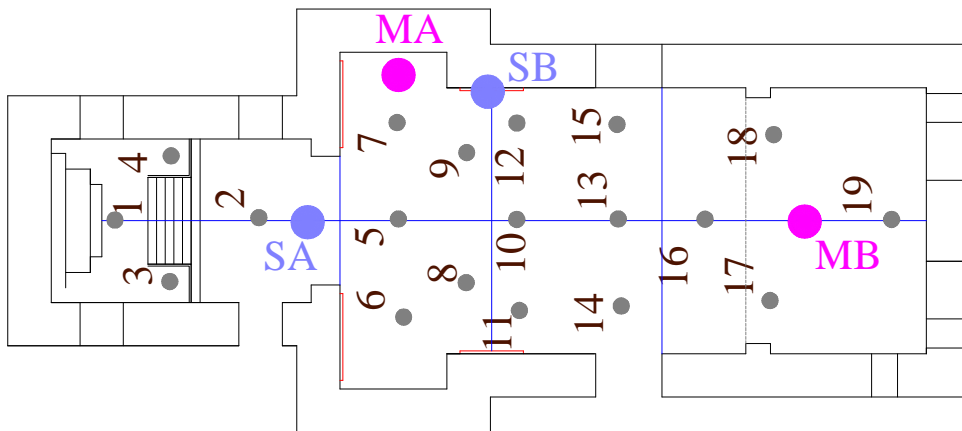


Figure 2: The locations of Listeners and Signal Sources (Speech and music).

The speakers (a Catholic Priest and a Lady Theatre Art Professional) alternately read out selected 50 words in Konkani and English languages from the prepared Modified Rhyme test [MRT] word lists. The Cellist played “Bach’s Suite No. 2”. The violinists and the human whistle played “Motet: Fera Pessima” a traditional Christian Lenten hymn. The ensemble played a Goan devotional classic “Piedade Saibinni in minor and major”.

3.2 Subjective Evaluation method

The acoustic evaluation sheet [3] [7] given to the listeners was interpreted to accommodate parameters of worship. The experience of reverential awe was expressed as an average of the following desirable Subjective Acoustic Impressions (SAI): Subjective Acoustic Impression of Intimacy (SAI_{INT}), Subjective Acoustic Impression of Envelopment (SAI_{ENV}), Subjective Acoustic Impression of Reverberance (SAI_{REV}), Overall Subjective

Acoustic Impression (SAI_{OVER}). The quality of Intelligibility of speech, singing and music was judged as an average of the following desirable Subjective Acoustic Impressions (SAI): Subjective Acoustic Impression of Loudness (SAI_{LOUD}), Subjective Acoustic Impression of Clarity (SAI_{CLAR}), Subjective Acoustic Impression of Directionality (SAI_{DIR}), Subjective Acoustic Impression of Balance (SAI_{BAL}). The quality of silence was judged from the following undesirable Subjective Acoustic Impressions (SAI): Subjective Acoustic Impression of Echoes (SAI_{ECHO}) and Subjective Acoustic Impression of Background Noise (SAI_{NOIS})

The Subjective Speech Intelligibility Index (SSII) is the averaged and indexed value of the % words understood by the listener. The subjective data was analyzed using *Excel* and *Origin 6.1*.

3.3 Measurement of objective acoustic parameters

The objective acoustic parameters [Noise Ambience (L_{eq}), Reverberation Time (RT), Loudness (G), Rapid Speech Transmission Index (RASTI) and Energy Time Graph (ETG)] were directly measured in unoccupied churches using the ‘*Terrasonde Audio Tool Box 2.0*’ [henceforth coded as ‘ATB’] and ‘*Terralink*’. A detailed Energy-Time Graph [ETG] analysis in compliance with the ISO-3382 standard [8, 9, 10], generated the following important objective monaural acoustic parameters: Definition [D_{50}], Clarity [C_{80}], Initial Time Delay Gap [ITDG], Center time [TS], Early Decay time [EDT].

3.4 Normalization of acoustic parameters

Various subjective and objective acoustic measures were normalized such that the normalized parameters are equal weighted constituents of the hypothesized Acoustic Worship Indices (AWI). The Semantic scale limits were used as a reference for the normalization of the subjective measures. A maximum word score of 100 was fixed as an upper reference limit for the SSI. An upper limit of 20ms [11] was fixed as the reference for the normalization of ITDG. The optimal reference value for Equivalent Ambient Noise level (L_{eq}) was fixed as 35 dB based on existential conditions. The value of 35 dB reflected one of the lowest available noise ambience level in churches of Goa as found in the Capela do Monte. The remaining acoustic measures were normalized using prediction equations obtained through a regression analysis of the reported acoustic data of Portuguese Churches [12]. The Portuguese churches were chosen because the architectural genres of the Goan churches like Capela do Monte selected for this study are partial derivatives of the Portuguese style. Regression analysis was performed using *Origin 6.1*.

3.5 Derivation of Acoustic Worship Indices

The following acoustically constituted worship parameters were derived:

3.5.1 Sacred Factor (SaF)

SaF as worship parameter was a description of the evolution from *Awe* to *Reverence* and *Metanoia*.

Acoustically, it was hypothesized that the perception of the overall subjective Acoustic Impression (SAI_{OVER}) has a tone of reverential *Awe* and a subtle urge for the Divine when it is accompanied by: a sufficient bonding with the source (SAI_{INTI}) and a sense of being immersed (SAI_{ENV}) into a vibrant ambience (SAI_{REV}). It was also hypothesized that the objective acoustic parameters: RT, G_{MF} and Objective Intimacy (which was calculated from the measured Initial Time Delay Gap observed in the Energy Time Graph), need to be sufficiently optimized as the corresponding counterparts of the chosen subjective acoustic parameters to comprehensively constitute the religious experience denoted by the ‘Sacred Factor’ (SaF).

3.5.2 Intelligibility Factor (InF)

Theologically, InF measures the quality of the communion between the ‘Word’ [13, 14] and the ‘Listener’. It also measures the intelligibility of the communication between the ‘human’ and the ‘divine’.

Acoustically, it was hypothesized that the music played in a church had to be perceived as *loud* (SAI_{LOUD}), *clear* (SAI_{CLAR}), *well-directed* (SAI_{DIR}) and *balanced* (SAI_{BAL}) in its bass and treble tones, in order to satisfy the conditions of intelligibility of *Sacred Music*. The subjective scores of the Modified Rhyme Tests (MRT) for speech termed as Subjective Speech Intelligibility (SSI) scores were hypothesized to be the sufficient subjective intelligibility determinants for speech. Among the objective parameters, Rapid Speech Transmission Index (RASTI) and Early to Total Sound Energy fraction (D_{50}) were hypothesized as objective measures of intelligibility of speech while the Early to Late Sound Energy fraction (C_{80}) and the Center Time for music (TS) were hypothesized as objective measures of intelligibility of Music. The Early Decay Time (EDT) of the Energy curve is important to gauge the intelligibility of speech as well as music and therefore is hypothesized as an independent objective measure of intelligibility. These objective parameters would need to be sufficiently optimized as the corresponding counterparts of the chosen subjective acoustic parameters to comprehensively constitute the religious experience denoted by the ‘Intelligibility Factor (InF)’.

3.5.3 Silence Factor (SiF)

Theologically, SiF covers the extensive journey from *solitude* to *serenity* to *surrender* that a worship space animates one into.

Acoustically, it was hypothesized that in order to optimize the effect of speech and music in the sacred liturgy an ambience of silence was necessary therefore subjective impressions of echoes (SAI_{ECHO}) and background noise (SAI_{NOIS}) were undesirable. The Equivalent Ambient Noise level (L_{eq}) was hypothesized as the objective counterpart for the characterization of ‘Silence’. These subjective and objective parameters when normalized were converted and construed as positive determinants of the ‘Silence ambience’ and as such comprehensively constituted the religious experience denoted by the *Silence Factor (SiF)*.

4 RESULTS AND IMPLICATIONS

4.1 Subjective Acoustic Impressions

Different subjective acoustic impressions were evaluated inside Capela do Monte and a comparison of their mean values is shown in Figure 3. The observed higher score for SAI_{CLAR} very grossly implied a subjective setting for acoustic intelligibility in Capela do Monte.

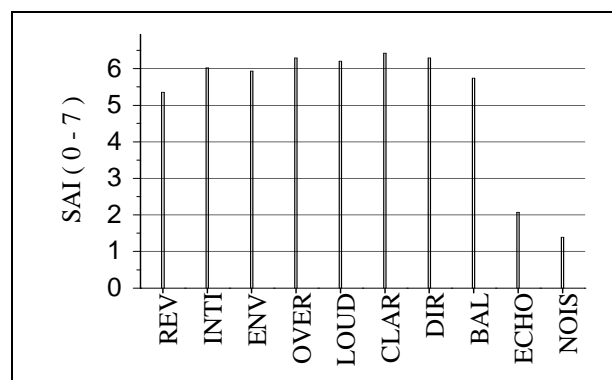


Figure 3: Comparison of Mean subjective acoustic impressions.

4.2 Subjective Speech Intelligibility

A detailed positional variance of mean SSI for the different sources (SA), (SB) and languages (KONK), (ENG) and the church (CH) is shown in Figure 4.

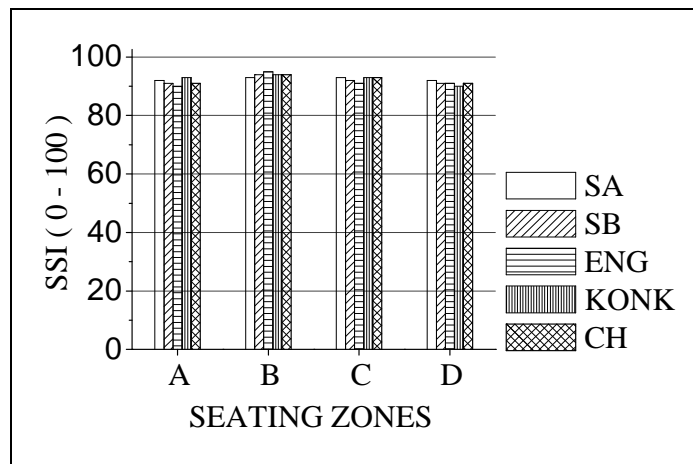


Figure 4: Positional Variance of SSI.

The mean Subjective Speech Intelligibility (SSI) in Capela do Monte was found to be fractionally better from the altar (SA) and the language 'Konkani' than from the pulpit (SB) and the language 'English' respectively for the listeners seated in the sanctuary and in the middle of the nave as observed in Figure 4.

4.3 Surrounding Noise Survey

A recording of the ambient noise as received inside the church at the center of the nave generated a curve as shown in Figure 5. The peaks levels rose to around 40 dB. A value of $L_{eq} = 35$ dB for the noise ambience inside the church implied that Capela do Monte had a very ideal objective ambience for silence and contemplation.

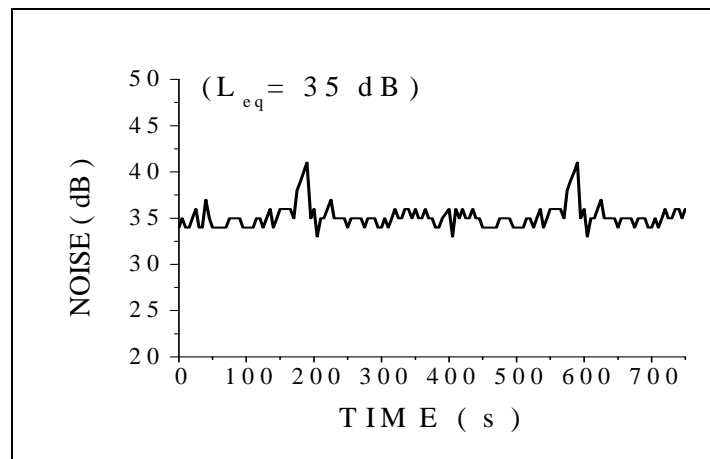


Figure 5: Noise ambience.

4.4 Reverberation Time (RT)

The variance of the measured reverberation time in the different recording zones of the church is shown in Figure 6.

The average reverberation time measured in Capela do Monte was found to be 5.17 s. The *narthex* (Zone 'D') reporting a value of 5.46 s was found to be the most reverberant space inside this church.

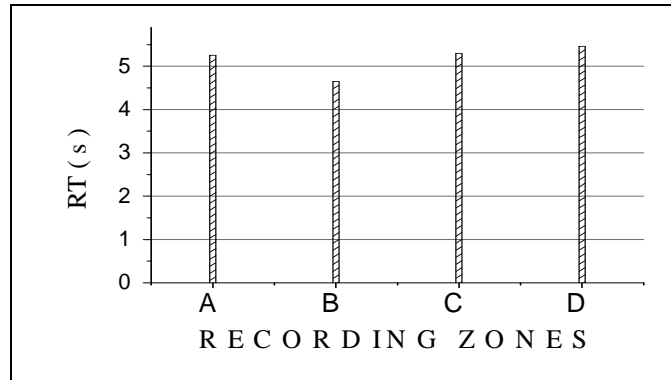


Figure 6: Variance of RT.

4.5 Rapid Speech Transmission Index (RASTI)

The variance of mean RASTI values in Capela do Monte for the standing (STAND) mode and the sitting (SIT) mode of the device and also for Source 'A' (SA) and Source 'B' (SB) in the different recording zones of the church is shown in Figure 7.

Better values of RASTI were recorded in the sitting mode of the device rather than the standing mode in all the zones of the church. The altar location (SA) favored RASTI in zones 'A', 'B' and 'D' whereas the zone 'C' showed a higher value of RASTI in favor of the pulpit location (SB). Zone 'B' showed comparatively higher RASTI scores. The northern section of the nave floor (Zone 'B') seemed to be the more conducive space for intelligibility based on the RASTI scores which implied that the spoken Liturgy would have its optimal effect on the congregation seated in this zone. The seating posture (SIT) seemed to be more favorable than standing (STAND) and the altar position (SA) a better source than the pulpit (SB) for an optimal effect of the spoken liturgy and for intelligible singing and music.

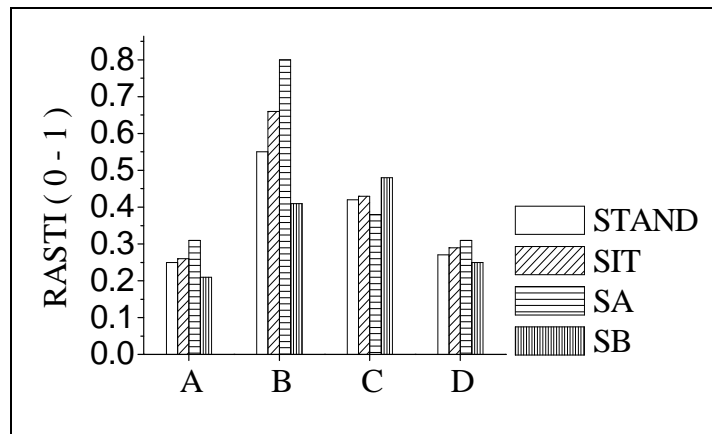


Figure 7: Positional Variance of RASTI.

4.6 Energy Time Graph (ETG)

The decay pattern for sound over time in the church was recorded and is shown in Figure 8.

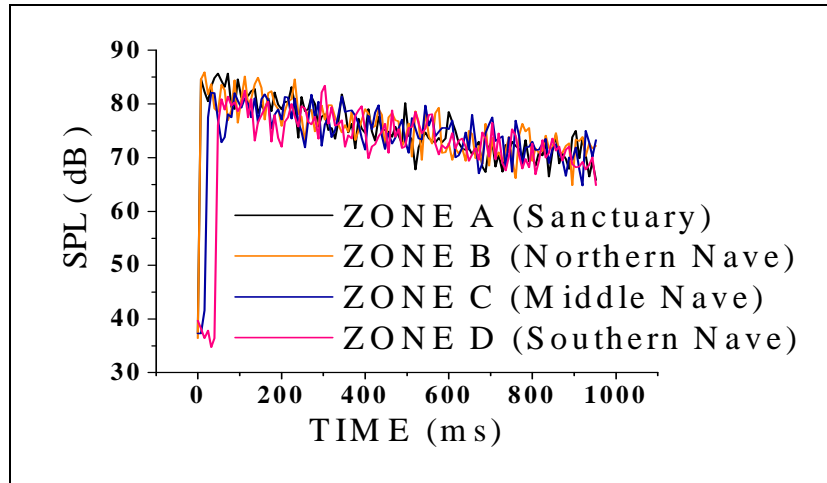


Figure 8: Energy Time Graph.

The monaural acoustic measures obtained from the ETG for Capela do Monte are shown in Table 2.

Table 2: Summary of the acoustic parameters calculated from the ETG.

LOCATION	D_{50}	C_{80}	TS	ITDG	EDT	G_{MF}
	[0 - 1]	dB	[ms]	ms	[s]	dB
2	0.23	-3.16	234	40	3.90	16.87
5	0.18	-4.96	271	16	4.32	16.34
13	0.10	-6.34	336	40	5.39	16.91
19	0.16	-5.01	336	16	5.04	17.04

The values of the acoustic measures shown in Table 2 suggest that the sanctuary (Location 2) of Capela do Monte was a better zone for clarity of speech and music considering the values of D_{50} , C_{80} , TS and EDT. The northern and the southern zones of the nave (Location 5 and Location 19, respectively) registered better objective intimacy with an initial time delay gap of 16ms. The southern zone of the nave was the loudest with a value of G_{MF} equal to 17.04. This would help to identify as to which section of the congregation had a more intelligible first impression of the liturgy and which section of the congregation had a more intimate first impression of the sacred liturgy.

4.7 Acoustic Worship Indices (AWI)

4.7.1 Normalized Acoustic Data

The normalization of the different subjective and objective acoustical measures was done as described in Section 3.4. The averages of the measured and the normalized values of all the acoustic parameters in Capela do Monte are shown in Table 3.

Table 3: Measured and normalized values of Acoustic Parameters (The Averages in the Church)

Parameter	Measured VALUE	Normalized VALUE (0 - 1)	Parameter	Measured VALUE	Normalized VALUE (0 - 1)
SaF (0 - 1)	0.79	0.79	L_{eq} (dB)	35.43	0.99
InF (0 - 1)	0.71	0.71	SAI_{REV} (0 - 7)	5.35	0.76
SiF (0 - 1)	0.87	0.87	SAI_{INTI} (0 - 7)	6.02	0.86
ACII (0 - 1)	0.56	0.56	SAI_{ENV} (0 - 7)	5.93	0.85
RT (s)	5.17	0.73	SAI_{OVER} (0 - 7)	6.29	0.90

G_{MF} (dB)	16.79	1.00	SSI (0 - 100)	92.21	0.92
ITDG (ms)	28	0.50	SAI_{LOUD} (0 - 7)	6.20	0.89
RASTI (0 - 1)	0.39	0.68	SAI_{CLAR} (0 - 7)	6.42	0.92
D_{50} (0 - 1)	0.17	0.85	SAI_{DIR} (0 - 7)	6.29	0.90
C_{80} (dB)	-4.87	0.35	SAI_{BAL} (0 - 7)	5.74	0.82
Ts (ms)	294	0.60	SAI_{ECHO*} (0 - 7)	2.07	0.70
EDT (s)	4.66	0.30	SAI_{NOIS*} (0 - 7)	1.39	0.80

The Acoustic Worship Indices (AWI): Sacred Factor (SaF), Intelligibility Factor (InF) and Silence Factor (SiF) were acoustically constituted and derived using the procedure described in Section 3.5.

4.7.2 Sacred Factor (SaF)

The variance of SaF in the different zones of the church is shown in Figure 9.

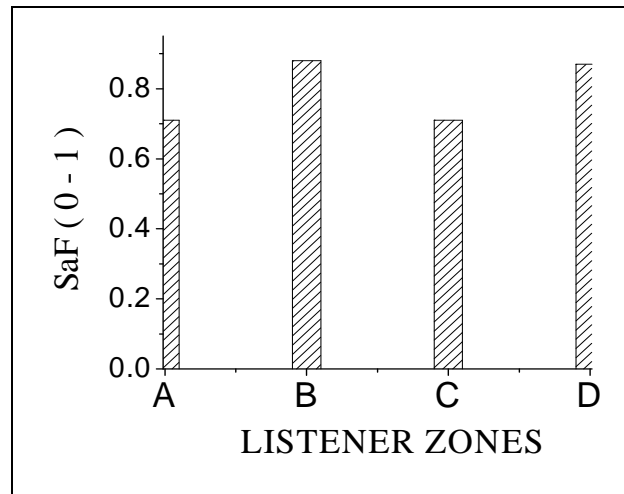


Figure 9: Zonal Variance of SaF in Capela do Monte

The mean value of SaF in Capela do Monte was found to be equal to 0.79 with a standard deviation of 0.09. It was also observed that the northern and the southern sections of the nave of the church had a better value of SaF (0.88, 0.87 respectively).

Looking from the theological perspective the averages of SaF in the different areas of the church revealed that the northern and the southern sections of the nave would be the areas where the congregation was likely to experience a comparatively higher magnitude of *Awe*, *Reverence* and an urge for *Metanoia*.

4.7.3 Intelligibility Factor (InF)

The variance of InF in the different zones of the church is shown in Figure 10

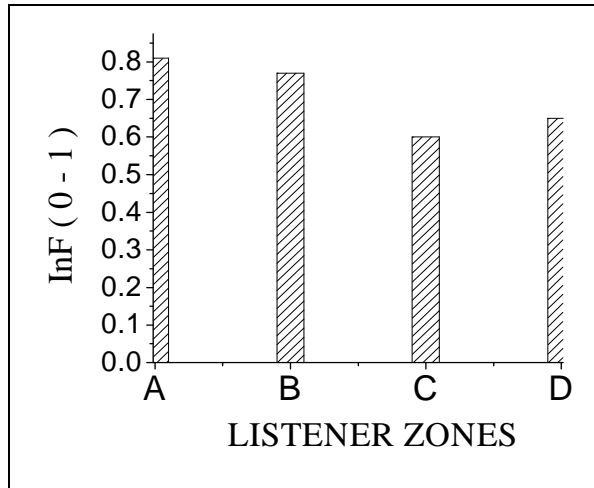


Figure 10: Zonal Variance of InF in Capela do Monte

The mean value of Intelligibility Factor (InF) in Capela do Monte was found to be equal to 0.71 with a standard deviation of 0.1. The sanctuary (Zone A) of the church showed the better value of InF.

Looking from the theological perspective, the averages of *InF* in the different areas of Capela do Monte revealed that the congregation was likely to experience a comparatively higher magnitude of *Communion, Meaning and Wisdom* in the sanctuary of the church.

4.7.4 Silence Factor (SiF)

The variance of SiF in the different zones of the Church is shown in Figure 11.

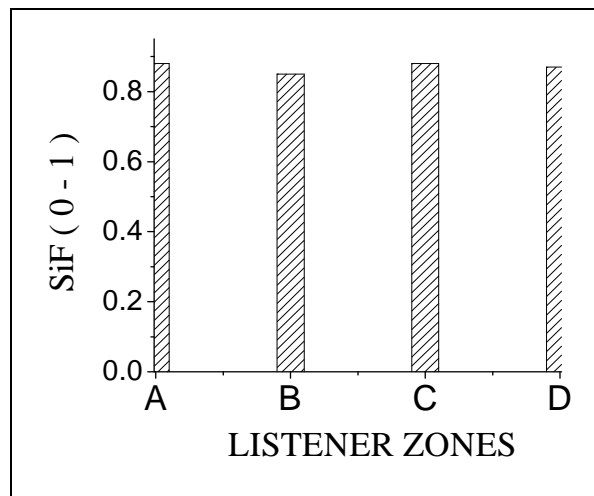


Figure 11: Zonal Variance of SiF in Capela do Monte

The mean value of Silence Factor (SiF) in Capela do Monte was found to be equal to 0.87 with a standard deviation of 0.01. The sanctuary (Zone A) of the Church showed the better value of SiF. The sanctuary and the middle section of the nave were found to be better spaces for subjective silence.

Looking from the theological perspective the averages of *SiF* in the different areas of Capela do Monte revealed that the congregation was likely to experience a comparatively stronger disposition of *Solitude, Serenity and Surrender* in the sanctuary of the church.

4.8 Best Correlations of the Acoustic Worship Indices (AWI)

The best Karl Pearson's Coefficients of correlation ($R \geq 0.6$) for the relationships between the Acoustic Worship Indices (AWI) and the objective and subjective acoustic measures are shown in Table 4.

Table 4: Best Positive and Negative correlations between the AWI and the acoustic measures

Parameter	POSITIVE CORRELATION				NEGATIVE CORRELATION			
	OBJECTIVE		SUBJECTIVE		OBJECTIVE		SUBJECTIVE	
	Parameter	R	Parameter	R	Parameter	R	Parameter	R
SaF			SAI _{ECHO*}	0.99	ITDG	-1.00	SAI _{REV}	-0.98
InF	D ₅₀	0.94			EDT	-0.99	SAI _{DIR}	-0.98
SiF	G _{MF}	0.92	SAI _{ENV}	0.98	RASTI	-0.86	SAI _{NOIS*}	-0.90

The Correlation figures (Cf. Table 4) indicated to the subjective perception of echoes, SAI_{ECHO}, as having a positive correlation with SaF pointing to the possible subtle positive correlation between *Echo* and the experience of *Awe*, *Reverence* and *Metanoia* in Capela do Monte. The negative correlation of SaF with ITDG implied that objective Intimacy was a dominant determinant of *Awe*, *Reverence* and *Metanoia* in Capela do Monte.

The negative correlation of SaF with the subjective perception of reverberance, SAI_{REV} indicated to the possible subtle negative correlation between *Reverberance* and the experience of *Awe*, *Reverence* and *Metanoia* in Capela do Monte.

The positive correlation of InF with D₅₀ and the negative correlation of InF with EDT identified D₅₀ and EDT as the possible intelligibility determinants of *Communion*, *Meaning* and *Wisdom* in Capela do Monte but the negative correlation of InF with the Subjective Acoustic Impression of Directionality (SAI_{DIR}) implied that the sense of directionality did not positively support the aesthetics of InF in Capela do Monte.

The negative correlation of SiF with RASTI and the negative correlation of SiF with the subjective perception of Background Noise (SAI_{NOIS}) suggested that too much intelligibility, just as much as too much perceived noise, may not support the experience of *Solitude*, *Serenity* and *Surrender* in Capela do Monte. Whereas the positive correlation of SiF with Loudness (G_{MF}) and the positive correlation of SiF with the Subjective Acoustic Impression of Envelopment (SAI_{ENV}) mooted the dependence of the aesthetics of SiF on the sound of speech, music and singing being loud and enveloping in Capela do Monte.

Thus knowing the degree of relationship between the different measured and derived acoustic variables we could choose certain significantly strong correlations to verify a functional relationship between the strongly correlating acoustic variables using the Regression analysis.

4.9 Prediction of Acoustic Worship Indices (AWI)

Different linear and non-linear regression models and also multi-regression models were explored and different significance tests done using *Origin* so as to ascertain the confidence in the predictability and measurability of the Acoustic Worship Indices (AWI): SaF, InF and SiF from the subjective and objective acoustic measures.

The best prediction equations for the averaged values of AWI along with their respective coefficients of determination, values of standard deviation and the 'F Statistic tests' probability values in the Church are shown in Table 5.

Table 5: Best Prediction Equations for the AWI.

NO	EQUATION	R ²	SD	p - value
1	$\ln F = 1.54477 - 0.30454 D_{50} - 0.16863 \text{ EDT}$	0.99	0.01	0.08
2	$\text{SaF} = 0.985 - 0.00688 \text{ ITDG}$	1.00	0.01	<0.01
3	$\ln F = 4.4 - 0.587 \text{ SAI}_{\text{DIR}}$	0.95	0.03	0.03
4	$\text{SiF} = - 47.36998 + 5.75321 G_{\text{MF}} - 0.17149 G_{\text{MF}}^2$	1.00	0.001	0.05

A confidence greater than 99% ($p = 0.01$) was generalized and denoted as ‘ $p < 0.01$ ’.

The Multiregression of $\ln F$ on D_{50} and EDT showed a coefficient of determination, $R^2 = 0.99$ with a standard deviation, $SD = 0.01$ and 92% level of confidence (shown by ‘F – Statistic’, $p - value = 0.08$) in the significance of the Fit. (Cf. Equation 1 in Table 5). $\ln F$ in Capela do Monte could therefore reasonably be expected to depend on both D_{50} and EDT.

While graphically representing the fits, the standard error of estimates (computed by *Origin 6.1* as a square root of the mean of squared deviations) were also plotted as vertical bars showing the vertical distances of every data point from the line or curve of average relationship. The 95% Upper Prediction limits (UPL) and Lower Prediction limits (LPL) and the 95% Upper Confidence limits (UCL) and Lower Confidence limits (LCL) limits were also shown in the plots. The Best Fits of the AWI on the acoustic measures along with the regression equation, Prediction and Confidence Limits and the Standard Error Bars are shown in Figure 12, Figure 13 and Figure 14 respectively.

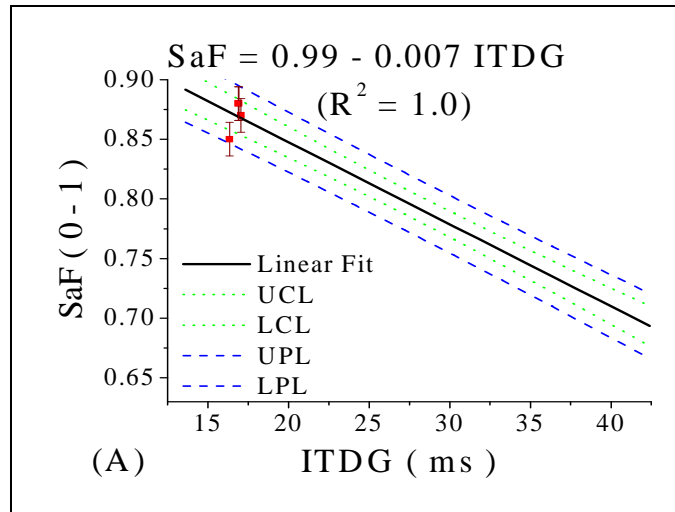


Figure 12: Linear Fit of SaF on ITDG

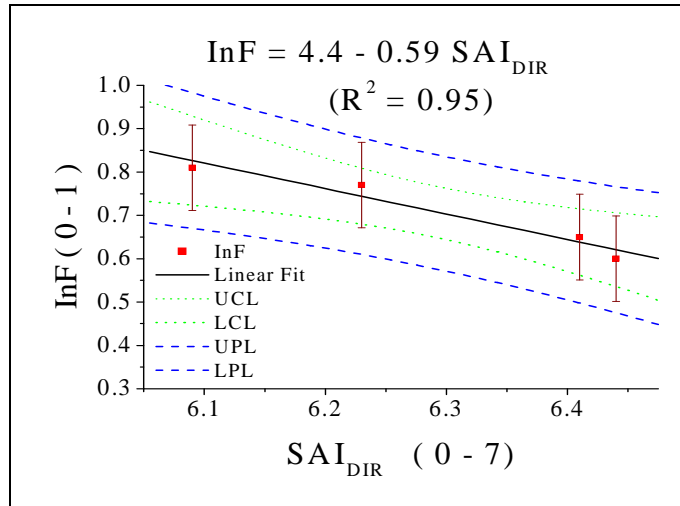


Figure 13: Linear Fit of InF on SAI_{DIR}

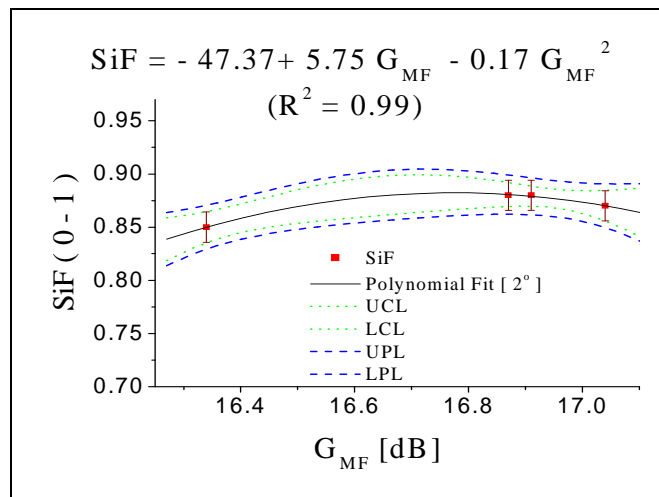


Figure 14: Polynomial Fit of SiF on G_{MF}

A linear regression line with a coefficient of determination, $R^2 \sim 1$ with a standard deviation, $SD=0.01$ and an ‘F-Statistic’, $p\text{-value} < 0.01$ (Cf. Equation 2 in Table 5) suggested a near perfect functional relationship between SaF and ITDG since ITDG could significantly determine SiF with more than 99% level of confidence.

InF could be determined by subjective directionality (SAI_{DIR}) with a coefficient of determination, $R^2=0.95$ with a standard deviation, $SD=0.03$ and 97% confidence level (as shown by its ‘F-Statistic’, $p\text{-value}=0.03$) in the significance of its linear Fit. (Cf. Equation 3 in Table 5).

The Quadratic relationship of SiF with G_{MF} was based on a coefficient of determination, $R^2 \sim 1$ with a standard deviation, $SD=0.001$ and an ‘F-Statistic probability’ $p\text{-value}=0.05$ (Cf. Equation 4 in Table 5) indicating to a significant functional relationship of 95% confidence level.

5 SUMMARY

The introductory historical note located Capela do Monte in its historical and architectural setting. The architectural details of the church were tabulated. The averaged data of the subjective and objective acoustic measures in the church was tabulated or graphed and normalized. These normalized acoustic indices were used to derive the ‘Acoustic Worship Indices’. The acoustic characterization of the worship ambience in Capela do Monte was

done using these acoustically constituted and derived ‘Acoustic Worship Indices’(AWI) namely: Sacred Factor (SaF), Intelligibility Factor (InF) and Silence Factor (SiF). The AWI showed significant relationships with a number of subjective and objective acoustic measures. The implications of the different acoustic measures and their relationships were noted. A Regression Analysis of the most significant of these relationships showed the plausibility of confidently predicting and measuring the “Worship Ambience” in Capela do Monte as described by the ‘*Acoustic Worship Indices*’ (AWI). These prediction equations of the AWI showed the possibility of evaluating and designing a “*Tranquil Worship Mood parameter*” in a Church, from measured and calculated acoustic parameters.

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