Certainties and uncertainties from using a selection of data to predict concert hall preference

Magne Skålevik (msk@brekkestrand.no)
AKUTEK and Brekke & Strand
PB 1024, 0218 OSLO
NORWAY

ABSTRACT

Over the past hundred years or so, many researchers have explored the possible correlation between physical properties of the concert halls and listeners assessment of the acoustics of the same halls. And we are still searching and researching. This author has previously shown how some sets of room acoustical parameters can, with their appropriate qualifying criteria, be used to explain the subjective ranking of a selection of halls from Beranek's rank ordering of 58 halls. A set of five listening aspects in ISO-3382 seems to be important, but trials with even more physical quantities have provided more explanation potential. A critical limitation in the research turned out to be the lack of sufficient amount of subjective AND objective data, leading to the launch of an online concert hall acoustics rating survey. In this paper, the latest results from this author's investigation are presented, featuring a demonstration of how the size of selected data affects the statistical uncertainties in such results. Remaining uncertainty in the prediction method naturally leads to a "safety first" policy with strict acceptance limits for the objective data. As a consequence, many appreciated halls would not be recommended for replication. These and other consequences need to be discussed in further work.

1 INTRODUCTION

Concert hall acoustics are very difficult and expensive to improve once the hall has been built. Thus there is high demand for safe methods to predict the public preference for the concert hall. Listeners' aspects and corresponding physical quantities suggested in ISO-3382 are widely accepted descriptors of concert hall acoustics. However, it remains to prove that they can be used for predicting listeners' preference for concert halls.

Over the past hundred years or so, many researchers have explored the possible correlation between physical properties of the concert halls and listeners assessment of the acoustics of the same halls. Rather soon after Sabine introduced the Reverberation Time, it became evident that two halls with the same RT could differ significantly as to listeners' preference. The pursuit after the perfect set of parameters began. And we are still searching. This author has previously shown how some sets of room acoustical parameters can, with their appropriate qualifying criteria, be used to explain the subjective ranking of a selection of halls from Beranek's rank ordering of 58 halls. A set of five listening aspects in ISO-3382 seems to be important, but trials with even more physical quantities have provided more explanation potential. In this context, explanation does not necessarily include full insight in underlying processes.

A critical limitation in the research has turned out to be the difficulty in finding a large enough selection of halls with sufficient amount of subjective AND objective data. An online concert hall acoustics rating survey is launched in order to collect more data, and anyone interested are invited to participate in the survey on https://www.surveymonkey.com/s/MMFMZ5W

In this paper, the latest results from this author's work are presented, featuring a demonstration of how the size of selected data affects the statistical uncertainties in such results.

2 PREVIOUS WORK

A comprehensive review of the work by this author on the subject since 2008 has been presented in the 2012 Status Report[1]. A brief summary of reports follows.

2.1 IOA Oslo 2008 [2,3]

Few listeners experience a set of five ISO-3382 parameter values equal to the set of five hall-averages, raising the question whether hall averages really describes the listening conditions that affects the audience' judgment of the hall

2.2 BNAM Bergen 2010[4]

Objective quantities corresponding to the five ISO-3382 listener aspects are quite precisely predicted with the so-called TVr-predictors, i.e. functions of T30, Volume and source-receiver distance, based on Barron revised Theory; TVr-predictions of 126 points in 11 European halls were compared with measurements by Gade[5]. LF is difficult to predict, and substitute predictors for apparent source width are investigated.

2.3 ICA, Sydney 2010[6] , objective-subjective correlation

2.3.1 ***Parameters at listeners ears***

A test of correlation between objective data and subjective for 10 halls included in Beranek's Rank-ordering[7] of 58 halls was reported. 5 parameters corresponding to the 5 listener aspects in ISO-3382 were used. During the trials, six objective data sets (different combinations of computer-simulations, TVr-prediction and measurements) representing occupied conditions in the 10 halls are tested.

TVr-predictions came out with the highest correlation ($r^2 \approx 0.9$) with Beranek's ranking.

Computer simulations failed to predict subjective preference for the ten halls ($r^2 \approx 0.6$).

Predicted and measured LF failed to distinguish between good and bad halls, pointing at the inherent uncertainties from a limited selection of halls.

Uncertainties in the subjective assessment of one of the ten halls would result in significant change in data-correlation.

Unwanted consequences from using multiple linear regression or invalid assumptions of linear relationship between objective and subjective data were demonstrated.

Prediction of concert hall preference based on parameter values at listeners' ears turned out to require a wide range of acceptable parameter values. EDT values would need an acceptance range of ±4 JND in trials that showed high correlation between objective and subjective data. The four other parameters needed less tolerance, with G_{late} turning out to be the least fluctuating parameter, needing an acceptance range of ±2 JND.

A reminder of the uncertainty in the concert hall prediction business came from one of the results: If the prediction was right, one of the top ten halls among Beranek's 58 ranked halls should not have been built. It came out with the same predicted preference as the hall number three from the bottom.

2.3.2 *ICA, Sydney 2010, testing the relevance of a parameter*

A method for testing the relevance and justification of introducing extra parameters without requiring linear independency, i.e. orthogonal parameters, was presented[8].

2.4 IOA Dublin 2011[9]

Objective hall-average values correlates better with subjective data than do objective data at listeners' ears. Hall-averages provide explanation in terms of prediction, but leave us without insight in the underlying mechanisms.

2.5 BNAM Odense 2012[1]

A status report was given, reviewing the work on the subject by this author since 2008. Apparently, hall-averages provide scientific explanation in terms of prediction, but leave us in lack of insight into the underlying mechanisms.

3 EXTENDED INVESTIGATION WITH BERANEK'S DATA FOR 53 HALLS

3.1 Eight Parameters

More data is introduced in the investigation, as the number of halls is increased to 53, and the number of parameters is increased to 8. At the same time, correlation between subjective and objective data decreases from $r^2 \approx 0.9$ with the 10 halls to $r^2 \approx 0.6$-0.7 with the 53 halls. Objective and subjective input were again taken from Beranek's data. However, in order to provide EDT, C, G, G_{late} and G_{125Hz} for all the halls, TVr-predictors were used. Since objective data corresponding to Apparent Source Width (LF and 1-IACCe3) were available for just a smaller subset of halls, it was instead decided to use measures of conventional source-broadening properties like Width (W) and Height-to-Width ratio (H/W).

Assuming that a client would not accept halls with objective score equal to those in Class II and Class III (Beranek rank order >20), examples of halls acceptable for replication are presented in Table 1.

Results were presented at the AIA-DAGA conference in Merano, March 2013[10].

Table 1 Concert halls with acceptable properties, given the process and criteria in section 3.1

Hall	Rank	V (m^3)	r_{avr} (m)	T (s)	EDT (dB)	G (dB)	C (dB)	GL (dB)	H/W (1)	W (m)	Score (%)
Vienna Grosser Musikverinsaal	1	15000	29	2,0	2,0	4	-1	1	0,9	20	**75 %**
Berlin Konzerthaus (Shauspielhaus)	4	15000	25	2,0	1,9	4	-1	2	0,9	21	**75 %**
Tokyo Opera City, Concert Hall	6	15300	30	2,0	1,9	4	-1	1	1,1	20	**75 %**
Boston Symphony Hall	2	18750	32	1,9	1,9	2	0	-1	0,8	23	**63 %**
Amsterdam Concertgebouw	5	18780	29	2,0	1,9	3	-1	0	0,6	28	**63 %**

Dallas, Meyerson Symphony Center	11	23900	30	2,8	1,9	4	-3	2	1,0	26	**63 %**
Zurich Grosser Tonhalsaal	7	11400	28	2,1	2,0	5	-1	3	0,7	20	**50 %**
Basel Stadt Casino	9	10500	25	1,8	1,7	5	0	2	0,7	21	**50 %**
Cardiff, St Davis Hall	10	22000	29	2,0	1,9	2	0	-1	0,7	27	**50 %**
Berlin Philharmonie	16	21000	34	1,9	1,8	2	0	-1	0,3	43	**50 %**
Baltimore, Meyerhoff Symphony Hall	20	21530	34	2,0	2,0	2	-1	-1	0,6	29	**50 %**
Manchester Bridgewater Hall	-	25000	25	2,0	1,9	2	0	-1	0,9	26	**75 %**
Lucerne, Cultural Ctr. Concert Hall	-	18000	23	2,1	2,0	4	-1	1	1,1	22	**75 %**
Criteria				T (s)	EDT (dB)	G (dB)	C (dB)	GL (dB)	H/W (1)	W (m)	
Hall average, center value				2.0	2.0	4	0	3	1.0	23	
Tolerance ±				0.1	0.2	1	1	1	0.2	5	

3.2 Contradiction or inevitable consequence of uncertainty?

A consequence of the assumption in 3.1 above is that 6 of the top 20 halls should not be built, one of these being Carnegie Hall, New York. Immediately this result would seem like a contradiction between input and output: “Carnegie Hall is first class” results in “Carnegie Hall is not first class”. However, this is not the case. The assumption was that halls with the same properties as the Class II and Class III halls should not be built. In statistics, name and identity is irrelevant, and we assume that the halls would not be ranked differently if the assessors wer blindfolded and naïve to their identity (whether this assumption holds or not is a different, however interesting, discussion). As a consequence of a conservative “safety first” policy, due to statistical uncertainty, i.e. lack of precision in the prediction method, some of the Class I halls would need to be banned.

3.3 Twelve parameters

The investigation based on Beranek’s objective and subjective data for 53 halls was extended, by increasing the number of parameters from 8 to 12. After a similar iterative process, correlation reached a maximum of r^2=0.75, with parameters and acceptance criteria limits as given in Table 2. In the process, the objective score is calculated simply by rewarding each hall 100/12 %-points for each of the 12 parameter values that is within the criteria limits. 100% score for a hall means that all its parameter values are within the criteria limits, 0% means that the hall has no parameter values within the criteria limits, and so on.

Like with 8 parameters, assuming that a client would not accept halls with objective score equal to those in Class II and Class III (Rank>20), examples of halls acceptable for replication and halls NOT acceptable for replication are demonstrated in Appendix Table 6.

These results and a discussion of uncertainties and consequences were presented at ISRA 2013 in Toronto[11].

Table 2: The 12 parameters and the acceptance limits found in the iteration process

	L	LF	1-IACCe	ITDG	Tocc	Tunocc	EDT	G	C	G125-G	H/W	W	GL	V/S0T
Max	*38*	*0,23*	*0,74*	*31*	*2,14*	*3,00*	*2,29*	*5,0*	*1,0*	*3,1*	*1,3*	*32*	*2,5*	*65*
Min	*28*	*0,13*	*0,48*	*13*	*1,89*	*2,20*	*1,79*	*3,2*	*-0,7*	*1,0*	*0,77*	*20*	*0,3*	*57*

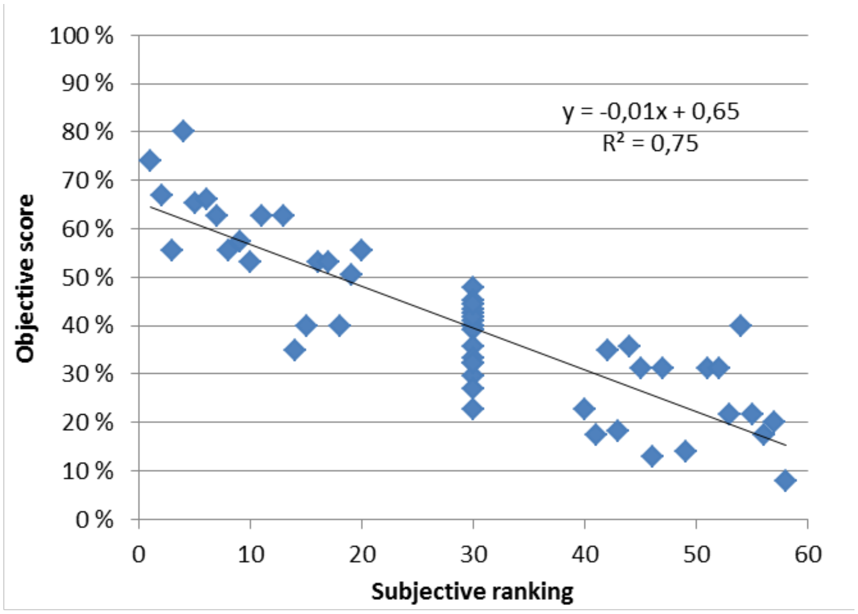

Figure 1 Objective score plotted against subjective ranking of 53 halls, based on the 12 parameter criteria in Table 2.

3.4 Uncertainties related to data size

Uncertainties related to changes in number of parameters and number of halls was demonstrated, see Figure 2. While reducing the number of parameters always resulted in lower correlation, a smaller selection of halls would result in greater uncertainty in correlation. A smaller subset of halls would randomly exhibit higher correlation, lower correlation, or practically unchanged correlation. With random selected subsets of e.g. 10 halls, correlation would vary between $r^2 \approx 0.15$ and $r^2 \approx 0.95$, clearly warning against drawing any conclusions from an apparently convincing r^2 outcome, either high or low, based on a low number of halls. With an expansion in terms of more parameters, not only correlation improved: Uncertainty is improved too.

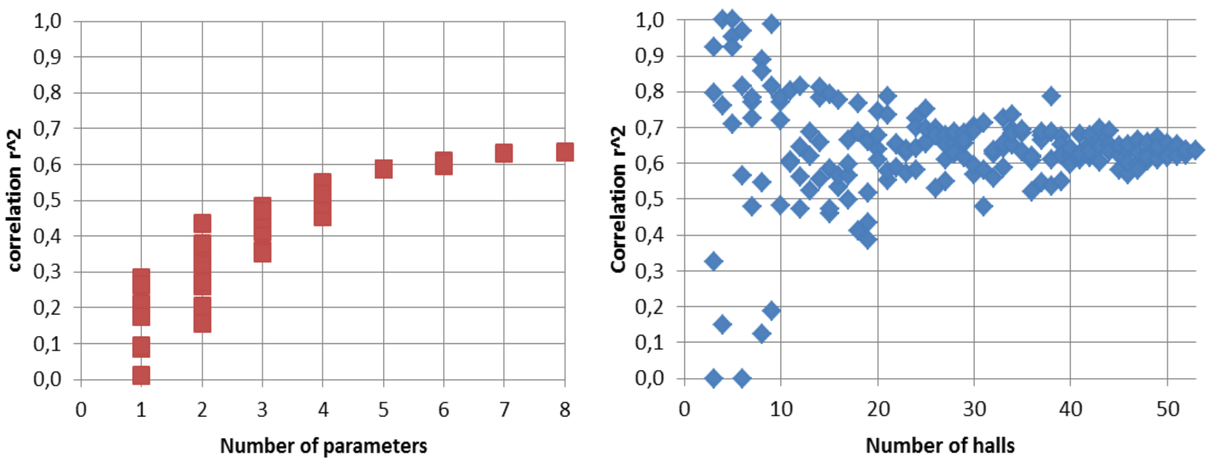

Figure 2: Correlation between objective and subjective data depending on the number of objective parameters (right) for 53 halls, and on the number of halls (left) with 8 parameters. See text.

4 ONLINE RATING OF 77 CONCERT HALLS

Since the uncertainty studies reported in 3.3 above demonstrated improved uncertainty in correlation with larger number of halls, an online concert hall rating was launched on https://www.surveymonkey.com/s/MMFMZ5W in November 2012, in an attempt to increase the number of halls from the 58 halls in Beranek's ranking to about 80 halls. All halls in the rating survey are represented with objective data in Beranek's data-collection, thereby providing for analysis of subjective-objective correlation in the data. Besides the quantitative increase in data, the survey had the potential of providing long demanded subjective data for halls built in the recent decades and therefore not included in Beranek's ranking. Among the newer halls of interest are the two un-ranked halls at the bottom of the list in Table 1. The rating survey is at the present still open to new respondents.

4.1 Selection of objective parameters

As demonstrated in Figure 2 in 3.3 above, an increase in the number of parameters coincides with improved correlation between objective and subjective data. Despite the marginal improvements seen in the increase from 5 to 9 parameters, it was decided to expand the objective data size by including up to 15 parameters. On the other hand, the number of parameters is naturally restricted by common availability. After all, the goal is to be able to predict subjective preference of future halls, and one should base such predictions to common available parameters, such as reverberation time and all the geometrical parameters. Experience from further work indicates that precise prediction of subjective source-broadening (ASW) can be difficult.

4.2 Question-and-response format and the organization of data

Our data collection was organized in a two 2D matrices, A and B. Matrix A has the dimensions Respondents vs Concert Halls, with entries in terms of points on a scale from 1 to 5:

“Much better than average” = 5, “Better than average” = 4, “Average” = 3, “Poorer than average” = 2, and “Much poorer than average” = 1. Respondents responded to the following question:

“In those halls in the list where you have attended a concert with a symphony orchestra once or more, how do you rate the acoustics there?”

Matrix B has dimensions Parameters vs Concert Halls, with entries in terms of parameter values.

The output from A is simply the average rating of each concert hall.

The output from B is a count of parameters having values within a criteria interval defined by a centre value and a tolerance. In case of a parameter with standardized JND, the tolerance was set close to JND. In other cases the tolerance was adjusted to optimize correlation between the outputs of A and B.

4.3 Testing the correlation between subjective (matrix A) and objective data (matrix B)

By running an iterative process where a large amount of combinations of different parameter criteria values was tested, the combination seen to optimize the r^2 (Pearson) correlation between A and B was chosen, see examples in Table 1 and Table 3. This set of parameter criteria is a by-product which potentially can be used to predict subjective preference of concert halls during the planning phase, given that the correlation was found satisfactory and given that consequences if applied to existing halls are judged acceptable, see discussion in 5.

4.4 Empty placeholders in the matrix

Until this point, this author has assumed that in order to make use of an extra parameter, the extra parameter would require data from all halls. However, the validity of this assumption is highly questionable, since it would imply an analogue argument for requiring all respondents to give ratings to all halls. Not only would the implications make a large-size investigation it practically impossible – it would introduce uncertainty from a reduced number of parameters and reduced number of respondents. In the end, to get a significant result, one would need parameters exhibiting a wide range of values, and responses exhibiting a wide range of rating values (points).

It was decided to accept empty placeholders both in the Respondents-Halls matrix and in the Parameters-Halls matrix.

4.5 Uncertainty from the number of responses per hall

With 326 ratings from 34 respondents, votes per hall counted from 1 to 14, on average 4.8 ratings per hall, and the 5% confidence interval containing the average rating of a hall was calculated to 0.6 points average. Response count was well distributed over halls in both ends of the rating scale without the suspected “since good hall draw more audience, there are potentially more respondents to these halls”. A high response count to the bad halls would be good for the significance of the results.

Every vote counts. If for instance 6 respondents gives one hall an average rating of 4 points (“better than average”), this would in practice count 6 times more than if only one respondent gave 4 points to this hall. Technically, this weighting is done for the data of each hall by multiplying its deviation from the average of all halls with the number of respondents. This weighting is applied to both subjective and objective data, Figure 3.

4.6 Results after 326 votes (data entries) from 34 respondents

After 326 votes (data entries) from 34 respondents, responding to 77 halls, using 15 parameters, an optimum correlation of r^2=0.80 is observed between the subjective and objective data, when data is weighted by the number of responses per hall, see Figure 3.

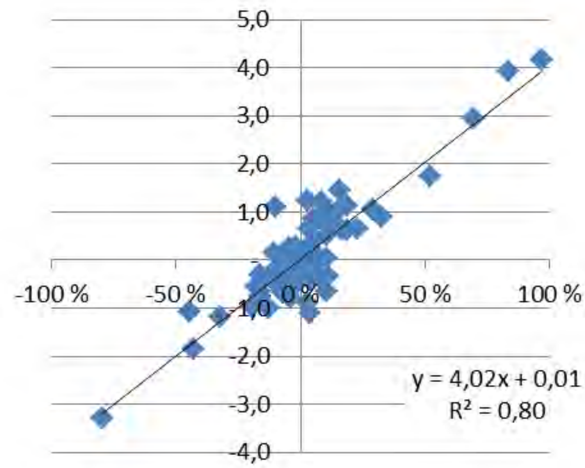

Figure 3 Each hall represented with a dot, its horizontal position represents its weighted deviation from the average objective score of all halls. Its vertical position represents its weighted deviation from average subjective rating of all halls. A zero hypothesis would be: “Only random deviation from average (here: the origin) will be observed”. Despite the lump around origin, instead of a circular formation, a clear linear formation is seen. Thus the argument for rejection of the zero hypothesis is illustrated. 77 halls, 326 votes from 34 respondents. Concertgebouw higher rightmost dot; Royal Festival Hall lower leftmost dot.

4.7 Testing a potential Preference Predictor

So far, we have just determined the parameter criteria that provide the optimal correlation between objective data and subjective preference. We developed a method which assigns to any hall an objective Score, i.e. a preference value between 0% and 100%. In order for the method to work as a Preference Predictor, we need to calibrate it by studying the subjective quality range associated with a given interval on the Score-scale. In particular, we do not want “bad halls” to be built, or “good halls” to be rejected in the planning phase. We want the percentage of overestimation and underestimation to be as small as possible in the prediction method.

Table 3 Parameter criteria values coinciding with optimum data correlation. S_0 is stage area in m^2.

Criterion	T	EDT	G	C	GL	A_{125}	V/TS_0	Au	N	H/W	L/W	W	LF	1-IACC	ITDG
Hall average, center value	2.1	2.0	3.0	0.0	2.3	1200	64	1200	1800	0.9	2.3	23	0.23	0.59	26
Tolerance ±	0.1	0.2	1.2	1	1	100	6	100	200	20 %	15 %	30 %	0.05	0.05	5

A division into a green “yes” group, a yellow “maybe” group, and a red “no group” is suggested. While the green group counts the top 10, the red group counts the bottom 22, the yellow group counts all of 45.Table 4 is a shorted version of the whole table, showing only 4 yellow halls. Few conflicts are found in green group, but the two respondents who vote against (2.5 points is less than average quality) Taipei Cultural Centre are overruled. Vienna Konzerthaus is supported by 5 votes claiming the acoustics there are between “better than average” and “much better than average”, despite its mediocre position in Beranek’s ranking (B58). In the red group, no halls except for Worcester are supported by subjective judgements.

A complete table of the yellow and red groups is presented in APPENDIX Table 7

The large size of the yellow group may be interpreted as an indication of uncertainty and a lack of significance in the results. In further work, this needs to be discussed.

Table 4 Top 13 halls, ranked by objective score, see text

Hall	rating	score	B58	N
Vienna Grosser Musikvereinsaal	4,8	60 %	1	12
Amsterdam Concertgebouw	4,7	60 %	5	14
Boston Symphony Hall	4,7	60 %	2	10
Lucerne, Cultural Ctr. Concert Hall	4,4	58 %		8
Vienna Konzerthaus	4,2	58 %	30	5
Tokyo Opera City, Concert Hall	4,3	57 %	6	3
Dallas, Meyerson Symphony Center	4,3	54 %	11	3
Manchester Bridgewater Hall	4,0	50 %		5
Taipei Cultural Centre, Concert Hall	2,5	50 %		2
Cardiff, St Davis Hall	4,4	47 %	10	5
Cleveland, Severance Hall	4,5	46 %	30	4
Tokyo, Orchard Hall	4,0	46 %	30	1
Leipzig, Gewandhaus	3,0	46 %	30	3
-	-	-	-	-

4.8 Uncertainties from data size

Uncertainties related to random sub-selections of the 77 halls and the 15 parameters are demonstrated below. The diagrams are comparable with Figure 2 in section 3.3, and similar features are seen.

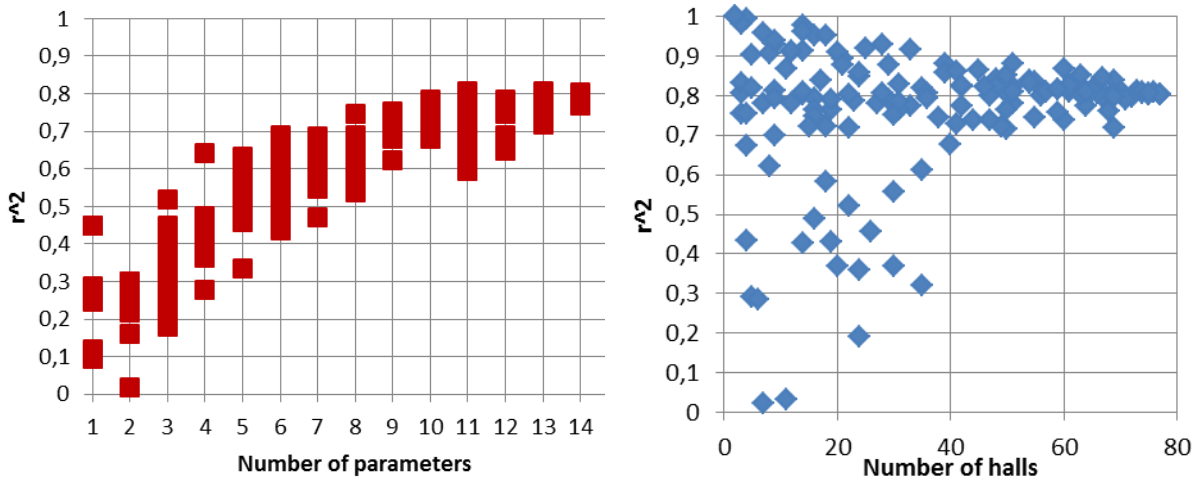

Figure 4 Correlation between objective and subjective data depending on the number of objective parameters (right) for 77 halls, and on the number of halls (left) with 15 parameters. See text.

4.9 Uncertainties in parameter criteria values

A comparison of criteria values resulting from two independent processes is presented in Table 5. Differences in T, EDT and G criteria values are equal to 1 just noticeable difference (JND), while C, GL, H/W and W are practically equal.

Table 5 Parameters and criteria values in terms of hall average values, two different data sets

Parameters and criteria	T (s)	EDT (dB)	G (dB)	C (dB)	GL (dB)	H/W (1)	W (m)
53 halls, Beranek ranking	2.0	2.0	4	0	3	1.0	23
77 halls, Online rating survey	2,1	1,9	3	0	2,3	0,9	23

5 RISKS IN CONCERT HALL PREDICTION BUSINESS

Uncertainty for a scientist translates to risk for a concert hall builder. Assuming the requirement that a new concert hall should have better parameter-score than the Class II and Class III halls (Rank>20) in Beranek's ranking of 58, there is the risk that some could-have-been-good halls may not be built, and some existing well-liked halls may not be replicated. On the other hand, a safety first policy by the client could mean the risk of losing freedom in design. Moreover, some of the unranked halls among the "approved" halls in Table 1 may turn out to be bad. Individual consequences of the resulting parameter-criteria in the different analyses in Table 2 in section 3.2 and Table 3 in section 4.7 are demonstrated in Appendix Table 6 and Table 7 respectively.

However, the inherent risk in the business of concert hall prediction, planning and decisions cannot be avoided. An ever increasing number of parameters ultimately lead to identical replication of the top ranked hall, revealing the uncertainty in the ranking process. Not even the strategy of making an exact replica of an existing building would be 100% safe, because other uncertainties than the objective ones would immediately become evident: "Vienna, Berlin, Tokyo, Boston or Amsterdam – we find them all great, but they all sound very differently, and we are not certain which one to choose." Besides, what if the client loves Concertgebouw but has only been there when the Concertgebouw Orchestra plays? Preference is based on listening experience, affected by the performance of the orchestra. Not with any strategy can uncertainty be eliminated, it can only be statistically limited.

6 CONCLUSIONS

A correlation of r^2=0.63 was found between objective and subjective concert hall data for 53 halls in Beranek's data collection, using 8 parameters. By increasing the number of parameters to 12, correlation increased to r^2=0.75. A tentative analysis of the current online rating, as acquired so far, and objective data for 77 halls in Beranek's collection showed r^2=0.80. However, the latter data exhibits slightly more uncertainty and parameter dependency than the former. Still, in general uncertainties appear to decrease uniformly as the number of concert halls and the number of parameters increase. Open placeholders in the data matrices can be handled: A respondent does not have to respond to all halls in the vector in order to increase significance; neither does a parameter need to have value entries for all the halls. LF and 1-IACCe data is available for a minority of the halls, and still contributes to increase correlation from 0.77 to 0.80. On the other hand, LF and 1-IACCe seems to be surprisingly well substituted by H/W and W. More parameters uniformly increases correlation and reduce uncertainty, and the number of parameters is in principle only restricted by availability and predictability. TVr predictors and geometrical data still prove to be very useful. Remaining uncertainty in the prediction method naturally leads to a "safety first" policy with strict acceptance limits for the objective data. As a consequence, many appreciated existing halls would not be recommended for replication, and some could-have-been-good halls would never be built. Loss of freedom in design can be a considerable price to pay for reduced uncertainty. These consequences need to be discussed in further work.

REFERENCES

[1] M. Skålevik, "Concert Hall Parameters – a status report", BNAM 2012, Odense, Denmark 2012 http://www.akutek.info/Papers/MS_ConcertHall_Parameters_2012.pdf

[2] M. Skålevik, "Room acoustic parameters and their distribution over concert hall seats", Proceedings of Auditorium Acoustics 2008, Institue of Acoustics, Vol.30. PT.3. 2008, ISSN 1478-6095, http://www.akutek.info/Papers/MS_Parameters_Distribution.pdf

[3] M. Skålevik, "Room acoustic parameters and their distribution over concert hall seats", Conference presentation, Auditorium Acoustics 2008, Oslo 2008. http://www.akutek.info/Presentations/MS_Parameters_Distribution_Pres.pdf

[4] M. Skålevik, "Reverberation Time, the mother of all acoustical parameters", Proceedings of ICA 2010 http://akutek.info/Papers/MS_reverberationtime_BNAM2010.pdf

[5] A. C. Gade, "Acoustical Survey of Eleven European Concert Halls", DTU Report No.44, 1989, ISSN 0105-3027

[6] M. Skålevik, "Room acoustical parameter values at the listener's ears – can preferred concert hall acoustics be predicted and explained?", Proceedings of 20th International

Congress on Acoustics, ICA 2010, Sydney, Australia. http://www.akutek.info/Papers/MS_Parameters_Explainability.pdf

7 L. Beranek, "Subjective rank-orderings for concert halls", Acta Acoustica u w Acoustica Vol 89 (2003) http://www.leoberanek.com/pages/eightyeighthalls.pdf

8 M. Skålevik, "Parameters' Relevance Test", a presentation at 20th International Congress on Acoustics, ICA 2010, Sydney, Australia. http://www.akutek.info/Presentations/MS_ParametersRelevanceTest_Pres.pdf

9 M. Skålevik, "On the struggle to find a set of room acoustical parameters that explains and predicts subjective ranking of concert halls", Auditorium Acoustics, IOA, Dublin 2011. http://www.akutek.info/Papers/MS_Acoustical_Parameters.pdf

10 M. Skålevik, "Room acoustical parameters - can concert hall preference be predicted?", AIA-DAGA 2013, Italian-German Meeting in Merano, Italy, March 2013. http://www.akutek.info/Presentations/MS_Preference_Prediction_Pres.pdf http://www.akutek.info/Papers/MS_Preference_Predictor

11 M. Skålevik, "Predicting Concert Hall Preference from Physical Quantities - Uncertainties related to selection of data", presentation, ISRA 2013, Toronto http://www.akutek.info/Presentations/MS_Preference_Uncertainties_Pres.pdf

12 Hiroyoshi Shiokawa and Jens Holger Rindel, "Comparisons between Computer Simulations of Room Acoustical Parameters and Those Measured in Concert Halls", Report of the Research Institute of Industrial Technology, Nihon University Number 89, 2007, ISSN 0386-1678

13 ISO 3382, ''Acoustics — Measurement of the reverberation time of rooms with reference to other acoustic parameters'' (1997): Annex A of later revisions.

14 L.Beranek, Concert Hall Acoustics—2008, J. Audio Eng. Soc., Vol. 56, No. 7/8, 2008 July/August http://www.slideshare.net/AdolfoPerez6/beranek-l-2008-concert-halls-acoustics

15 L. Beranek: Concert Halls and Opera Houses, second edition, Springer, 2003

16 M. Barron, Auditorium Acoustics and Architectural Design (E & FN Spon, London, 1993).

17 M. Barron, Using the standard on objective measures for concert auditoria, ISO 3382, to give reliable results, Acoust. Sci. & Tech. 26, 2 (2005)

18 M. Barron, "Objective assessment of concert hall acoustics", Proceedings of Auditorium Acoustics 2008, Institue of Acoustics, Vol.30. PT.3. 2008, ISSN 1478-6095 http://www.akutek.info/Papers/MB_Objective_Assessment.pdf

19 M Skålevik, "Reverberation Time – the mother of all room acoustical parameters", BNAM 2010, Bergen http://www.akutek.info/Papers/MS_reverberationtime_BNAM2010.pdf

20 M. Skålevik, http://www.akutek.info/Presentations/MS_ParametersRelevanceTest_Pres.pdf

21 L. Beranek, http://www.leoberanek.com/pages/concerthalls2008.pdf

22 Hidaka, Nishihara and Beranek "Relation of acoustical parameters with and without audiences in concert halls and a simple method for simulating the occupied state", J. Acoust. Soc. Am., Vol. 109, No. 3, March 2001, p 1028-1048.

APPENDIX: DATA TABLE

Table 6 Individual consequences from using Beranek's objective and subjective data for 53 halls, 12 parameters, in section 3.2. It is here assumed that only concert halls with better score than Class II (rank 21-39) in Beranek's ranking are accepted for replication. * = In agreement with rating in online survey. NOTE: If a hall is found in the "Score<50%" group, it does not necessarily mean that it is a bad hall which should not be replicated. Rather, it means that any replication has to be based on other ground than the parameter values in the analysis.

Score≥50% Replication supported	Score<50% Replication NOT supported
Valencia, Paleu de la Musica	Seattle, Benaroya Hall
*Lucerne, Cultural Ctr. Concert Hall	Sao Paolo, Sala Sao Paulo
*Manchester Bridgewater Hall	Minneapolis, Minn. Orchestra Hall
*Fort Worth, Bass Performance Hall	Kuala Lumpur, DewanFil. Petronas
Taipei Cultural Centre, Concert Hall	Budapest, Patricia Hall
Mexico City, Salla Nezahualcoyotl	Denver Boettcher Hall
Philadelphia, Verizon Hall	*Olavshallen, Trondheim
Baden-Baden Festspielhaus	Sapporo Concert Hall
Lahti, Sibelius/Talo	Athens, Megaron Concert Hall
Birmingham Symphony Hall	Belfast, Waterfront Hall
*Munich, Herkulessalle	Rochester, NY, Eastman Theatre
Odense, Koncerthus Nielsen Hall	Caracas, Aula Magna

Table 7 Individual consequences from using 15 parameters from Beranek's objective data and subjective data from the online ranking survey of 77 halls, grouped in the green "yes" group, the yellow "maybe" group and the red "no group", see text section 4.7. NOTE: If a hall is found in the yellow or red group, it does not necessarily mean that it is a bad hall which should not be replicated. Rather, it means that any replication has to be based on other ground than the parameter values in the analysis.

Hall	rating	score	B58	N
Vienna Grosser Musikvereinsaal	4,8	60 %	1	12
Amsterdam Concertgebouw	4,7	60 %	5	14
Boston Symphony Hall	4,7	60 %	2	10
Lucerne, Cultural Ctr. Concert Hall	4,4	58 %		8
Vienna Konzerthaus	4,2	58 %	30	5
Tokyo Opera City, Concert Hall	4,3	57 %	6	3
Dallas, Meyerson Symphony Center	4,3	54 %	11	3
Manchester Bridgewater Hall	4,0	50 %		5
Taipei Cultural Centre, Concert Hall	2,5	50 %		2
Cardiff, St Davis Hall	4,4	47 %	10	5
Cleveland, Severance Hall	4,5	46 %	30	4
Tokyo, Orchard Hall	4,0	46 %	30	1
Leipzig, Gewandhaus	3,0	46 %	30	3

Hall	rating	score	B58	N
Basel Stadt Casino	4,5	43 %	9	4
Berlin Konzerthaus (Shauspielhaus)	3,9	43 %	4	10
Zurich Grosser Tonhalsaal	3,6	43 %	7	4
Tokyo, Metropolitan Art Space	3,0	43 %	30	1
Lahti, Sibelius/Talo	4,7	42 %		3
Baden-Baden Festspielhaus	4,0	42 %		1
Munich, Herkulessalle	4,0	42 %		4
Minneapolis, Minn. Orchestra Hall	3,5	42 %		4
Baltimore, Meyerhoff Symphony Hall	3,0	42 %	20	3
Philadelphia, Verizon Hall, Kimmel Center	2,8	42 %		4
Christchurch, Town Hall	4,7	38 %	30	3
Lenox, MA, Seiji Ozawa Hall	4,0	38 %	13	2
Gothenburg Concert House	4,0	38 %	30	3
San Fransisco, Davies Hall	3,7	38 %	54	3
Edinburgh, Usher Hall	3,3	38 %	44	3
Liverpool, Philharmonic Hall	3,0	38 %	47	1
Berlin Philharmonie	3,9	36 %	16	13
Kyoto Concert Hall	3,5	36 %	30	2
Birmingham Symphony Hall	4,8	33 %		4
Fort Worth, Bass Performance Hall	4,0	33 %		5
New York Carnegie Hall	3,8	33 %	8	13
Shanghai, Grand Theatre	3,5	33 %		2
Brussels, Palais des Beaux-Arts	3,2	33 %	19	6
Budapest, Patricia Hall	3,0	33 %		1
Odense, Koncerthus Nielsen Hall	3,0	33 %		1
Trondheim Olavshallen	2,9	33 %		6
Seattle, Benaroya Hall	2,5	33 %		4
Osaka, Symphony Hall	3,0	31 %	30	1
Tokyo, Suntory Hall	3,8	29 %	17	4
Salt Lake City, Symphony Hall	3,3	29 %	15	3
Paris, Salle Pleyel	3,3	29 %	49	6
Rotterdam De Doelen	3,0	29 %	30	3
Stuttgart. Liederhalle Grosser Saal	3,0	29 %	41	5
Belfast, Waterfront Hall	3,5	25 %		2
Hong Kong, Cul. Ctr. Concert Hall	3,5	25 %		4
Toronto, Roy Thompson Hall	3,0	25 %	30	3
Madrid, Auditorio Nacional de Musica	3,0	25 %		3
Aspen, Benedict Music tent	2,3	25 %		3
Buenos Airos, Teatro Colon	4,0	21 %	3	1
Tokyo, Bunka Kaikan (Ueno)	4,0	21 %	18	2
Costa Mesa, Segerstrøm Hall	3,7	21 %	14	2
London, Barbican Concert Hall	3,0	21 %	56	9
Munich, Philharmonie Am Gasteig	2,6	20 %	30	5
Worchester Mechanics Hall	5,0	17 %		3
Sydney Opera House Concert Hall	3,2	17 %	53	5
Mexico City, Salla Nezahualcoyotl	3,0	17 %		2

Hall	rating	score	B58	N
New York, Avery Fisher Hall	2,8	17 %	42	13
Lenox, Tanglewood Music Shed	2,8	17 %	30	5
Washington, DC, JFK Concert Hall	2,8	17 %	30	5
Bonn Beethovenhalle	3,7	15 %	30	3
London Royal, Albert Hall	2,9	15 %	58	9
Chicago, Orchestra Hall	2,8	15 %	30	5
Glasgow, Royal Concert Hall	2,0	15 %	45	2
Tel Aviv, Frederic Mann Auditorium	2,0	15 %	55	1
Salzburg. Festspielhaus	2,8	13 %	40	4
Rochester, NY, Eastman Theatre	3,0	8 %		2
Sapporo Concert Hall	3,0	8 %		1
Tokyo, NHK Hall	2,5	8 %	52	2
Jerusalem, Binyanei Ha'Onnoh	4,0	8 %	30	1
Montreal, Salle Wilifrid-Pelletier	2,9	7 %	51	8
Buffalo Kleinhans Music Hall	2,0	7 %	57	1
Denver Boettcher Hall	4,0	0 %		1
Caracas, Aula Magna	3,0	0 %		1
London Royal Festival Hall	2,2	0 %	46	11