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STAIRWAY – A NEW APPROACH TO MODELLING OF PHYSICAL OR PERCEIVED NOISE

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ABSTRACT

The aim of this paper is to present a proposed notation system to describe empirical modelling for acoustics. StairWay is a database containing measured noise emission, transmission and immission. The physical or perceived noise in critical areas like living rooms, bedrooms, gardens, places of worship or others can be calculated from the database using simple models. So far only physical noise models have been introduced, we certainly hope to include models of perceived noise in the future.

The modelling is based on field measurements. At the core of StairWay is the database, where all field measurement results are stored. Two models from StairWay have been published earlier on, two different methods of calculating indoor traffic noise levels, Napoli and Mariehamn. These are based on outdoor spectra and level difference spectra, Mariehamn also takes exposed façade area and room volume into account. Other applications are continuously developed and published.

The basic principles of StairWay modelling are as follows:

- Field measurements form the basis of the models (no laboratory facilities required)
- All field measurements are stored for possible future use (open and extensible)
- Models are built on a continuously updated measurement database (heuristic)
- Expected uncertainty is computed along with the result (stochastic)
- Transfer functions are taken from field measurements, theoretical refinements are only added if they give significantly increased accuracy (mathematically minimalistic)

The most important operations in StairWay are:

- Select table, Ш operator, a Cyrillic letter corresponding to “zh”
- Select entry, Ξ operator, capital Greek epsilon
- Process table, φ operator, Greek phi
- Crosstab, Ж operator, a Cyrillic letter corresponding to “sh”
- Evaluation, Ω operator, capital Greek omega

1 INTRODUCTION

Empirical modelling is well known as an important tool within many branches of science and technology. In fact it's the way we learn new things every day. The figure below shows the main concept behind empirical modelling.

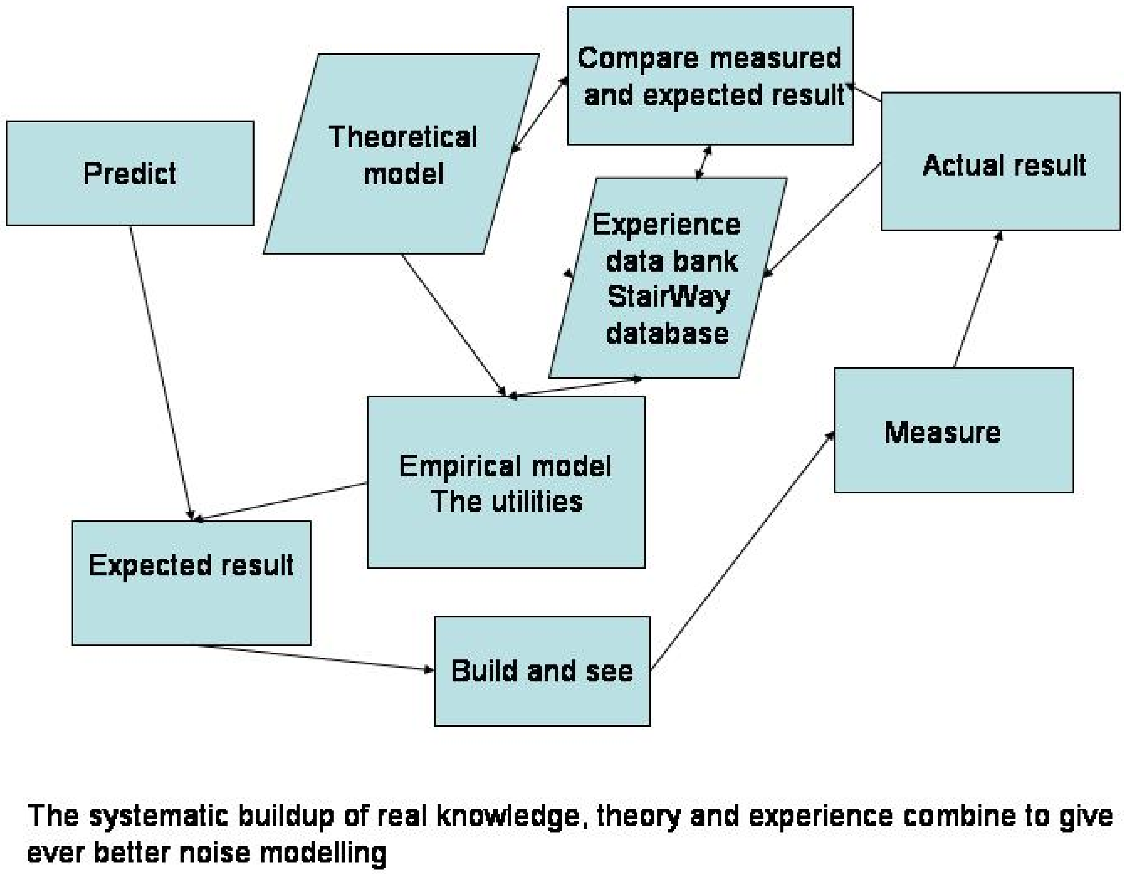

Figure 1 Underlying concept of empirical modelling

The acquisition of a reliable and sufficiently large database is the foundation for any type of empirical model. Without such a database, empirical models are not even conceivable. Empirical modelling must be heuristic, meaning that new experience could lead to the model giving different results. As the model gets better, new data will give gradually smaller changes in the results.

A practical problem is used to illustrate the theoretical concepts. The solution is based on the StairWay database. The following question has been chosen as an example:

How great is the difference in indoor traffic noise, given as 24-hour A-weighted Leq, between open and closed ventilation devices?

2 SELECT TABLE OPERATOR, Ш

This operator presumes that the database contains a large number of tables. Let's consider our chosen example again:

How great is the difference in indoor traffic noise, given as 24-hour A-weighted Leq, between open and closed ventilation devices?

Analysis of this task reveals that the A-weighted outdoor level can be measured or calculated with reasonable accuracy using a modest effort. There are three other factors that are not so easily determined:

1. Outdoor spectrum shape
2. Level difference spectrum through the façade with closed ventilation devices
3. Difference spectrum between open and closed ventilation devices

It's been shown [1],[2],[3] that databases of sufficient size and quality exist to calculate indoor traffic noise spectra with closed ventilation openings using empirical methods. StairWay now contains well over 2100 outdoor traffic noise spectra and well over 300 façade difference spectra. In addition, 48 difference spectra between open and closed ventilation devices have been assembled.

In our example case, the select table should be written as:

Ш Outdoor spectrum shape
Ш Level difference facade
Ш Open vs. closed ventilation

3 SELECT ENTRY OPERATOR, Ξ

Once a table has been selected, the relevant records in that table must be found. Suitable selection criteria are required. The definition of selection criteria is the key to successful empirical modelling. If selection criteria are too loosely and widely defined, the variation between the selected records will be too wide. If selection criteria are too strict and narrow, there'll be too few records.

As an example, it'll make sense to repeat the case that was used for the same purpose at the previous Euronoise conference in Napoli 2003 [1].

Ξ Outdoor spectrum shape (v=80 km/h, 10 m ≤ distance ≤ 30 m, -5 m ≤ height over line of sight ≤ 0 m)

Ξ Level difference façade (light wooden wall, double glazing, simple ventilation opening)

Ξ Open vs. closed ventilation (simple ventilation opening)

4 PROCESS TABLE OPERATOR, Φ

This example requires very little processing to produce meaningful level difference spectra. In some cases, of course, the data are not quite suitable for the purpose we want. The process table operator might be something as simple as A-weighting.

5 CROSSTAB OPERATOR, Ж

This operator is the one that starts turning data tables into a calculation model. The principle is as follows:

Start from an obviously true statement, like equation (1) below.

$L_{indoor} = L_{outdoor} - Diff_{facade}$	(1)
L_{indoor}: Indoor traffic noise level	
$L_{outdoor}$: Outdoor traffic noise level	
$Diff_{facade}$: Level difference between outside and inside	

The next step is critical: We set up the hypothesis that if we gather outdoor traffic noise levels and façade level differences, this knowledge can be used to predict indoor traffic noise levels. In our notation, this should read like equation (2) below:

A = Ж {B – C}	(2)
A: Indoor level, closed ventilation	
B: Ξ Outdoor spectrum shape (v=80 km/h, d=10 to 30 m, h= -5 to 0 m)	
C: Ξ Level difference façade (light wooden wall, double glazing, simple ventilation opening in closed position)	

The meaning of the statements is as follows:

The indoor traffic noise level in a given case can be estimated by combining outdoor spectrum shapes from similar situations with level differences through similar facades and then evaluate the table of results. This is done by first subtracting each case of level difference in the façade from each case of outdoor spectra. Then the average and the standard deviation of the insulation is calculated to produce an expected indoor level. Practice has shown that this can be done with convincing results [1], [2], [3].

The next step in our procedure will be to run a crosstab between the indoor level with closed ventilation and the difference between open and closed ventilation. In our proposed notation, this will be written as equation (3) below:

D =Ж {(A + E)-A}	(3)
A: Indoor level, closed ventilation from equation (2)	
D: Difference between open and closed ventilation opening	
E: Ξ Open vs. closed ventilation (simple ventilation opening)	

6 EVALUATION OPERATOR, Ω

The steps described above give us a set of spectra for the difference between open and closed ventilation devices. In the end this is a huge matrix. In this tested case at the current state of development of StairWay the size of this matrix is 2808 spectra, each with 21 1/3-octave bands. This information must be reduced to something that can give a comprehensible answer. In figure 2 below is shown the probability distribution of dBA difference with open and closed ventilation openings.

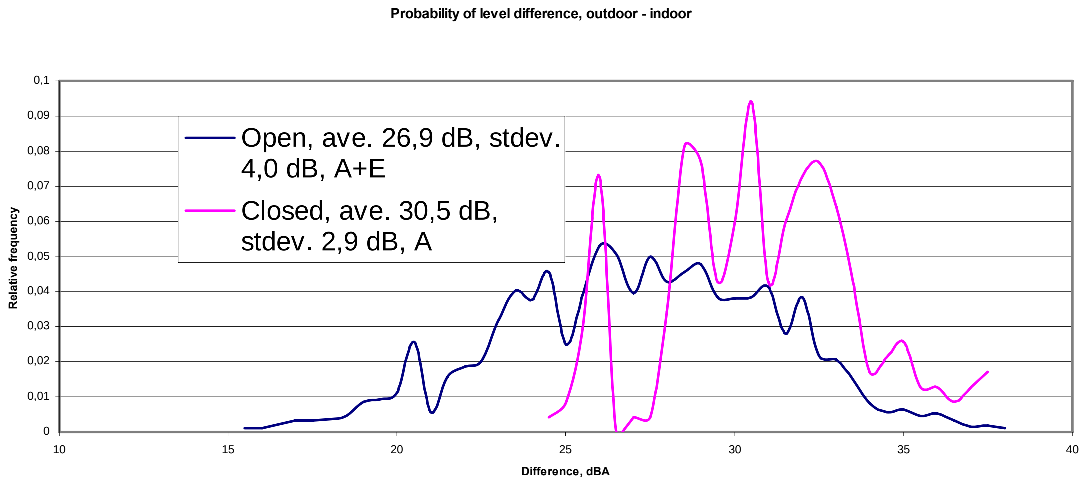

Figure 2. Probability distribution of difference between outdoor and indoor traffic noise level, with open and closed ventilation device, step width 0,5 dB, 234 cases closed ventilation, 2808 cases open.

Clearly more data will give smoother graphs. Our practical experience shows that the model gives a standard deviation of 2-4 dB when compared to direct measurements.

The evaluation operator is a definition of the transfer from the calculated matrix into a practical result. So far the only evaluation that has seen practical use has been to calculate the average and standard deviation of a single number rating like dBA, R'w, Ln'w.

In this case, it's tempting to say that our best current estimate is that a simple ventilation opening will give around 3-4 dBA higher indoor traffic noise level in the open position than in the closed position.

7 APPLICATIONS

Currently, the StairWay database system contains over 80 tables of sound emission, transmission and immission. The supported calculation models are as follows:

- Two methods of calculating façade sound insulation against traffic noise [1],[2],[3]
- The difference between open and closed ventilation openings (this paper)
- A prediction of R'w for lightweight partition walls, unpublished
- A prediction of vertical Ln'w for heavy floor construction, to be published
- A prediction of façade sound insulation against tram noise, to be published
- A prediction of sound power level emitted from road and rail tunnels

Our experience so far shows that an empirical approach will always be useful. The knowledge gained through the construction of the database will always be equally useful. A rough guideline for the information gained from empirical models seems to be as follows:

- 50 records A good supplement to theoretical methods
- 100 records Accuracy is comparable to theoretical methods
- 200 records A carefully built empirical method often outperforms theory
- 1000 records Empirical method usually outperforms theory

This is based on practical experience in a few cases. The performance of empirical modelling has been much better than should be expected given the number of parameters involved. It's a long term plan to include annoyance tables and calculation methods into the StairWay system.

8 CONCLUSION

Basic principles and a proposed notation for the construction of empirical models have been presented. Practice has shown that the most important criterion for the success of empirical models is the size and quality of the experience data base. It would be very interesting to carry out a theoretical study to investigate criteria for the required size of the database.

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