



The Impact of Input Parameter Resolution on Computational Efficiency in Façade Noise Mapping

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ABSTRACT

Environmental noise prediction software packages are essential tools within the field of building acoustics to evaluate external noise impacts on a building envelope. While modern prediction software packages offer high levels of detail and flexibility, the relationship between input data resolution and computational performance remains insufficiently explored. This study examines how variations in key input parameters including building façade detail level, reflection order complexity, surrounding environment details, and sound source priority affect both execution time and prediction accuracy. Practitioners often face the challenge of maintaining modelling accuracy within time and resource constraints. By systematically analysing how different parameters affect simulation runtime and result precision, this study aims to provide insights for optimising model setups. The findings presented correspond to the first phase of a broader investigation, focusing on SoundPLAN and a single project scenario. The results are intended to assist users in managing computational performance in facade noise mapping assessments.

1 INTRODUCTION

Environmental noise modelling plays a key role in urban planning and environmental impact assessment, particularly in densely populated areas where noise pollution directly affects public health and quality of life (WHO, 2018). Accurate models depend on precise and well-defined input parameters, but as the level of detail increases, so too do the computational requirements. Highly detailed models lead to longer computation times and higher resource demands, which can limit their practicality in day to day building consultancy projects. In many cases, especially when working with large study areas, dense urban environments, or to tight deadlines, the added accuracy gained from complex input configurations may not outweigh the cost in time and computational effort. Finding the right balance between model detail and computational efficiency is therefore essential for effective and manageable environmental noise assessments.

Available literature highlights the importance of input parameter resolution in balancing model accuracy and computational efficiency in environmental noise modelling. Miller and Parr examined the role of geometric detail and found that incorporating fine-scale urban features, such as detailed building outlines and façade elements, significantly enhanced prediction accuracy in complex urban settings. However, they noted that this level of detail also led to substantial increases in computation time and resource usage. Additionally, they cautioned that overly detailed but poorly calibrated models could result in over-predictions, emphasizing the need for a balanced approach to geometric input complexity (Miller and Parr 2013). Similarly, Song and Lenchine investigated the impact of spatial resolution on model performance. Their results showed that coarser spatial grids reduced computational load, making large-scale simulations more practical. Nonetheless, this efficiency gain came at the expense of prediction accuracy, particularly in shielded locations or areas with complex terrain and urban geometry where fine-scale variations in noise exposure are more critical (Song and Lenchine 2018).

While previous studies have explored the influence of modelling parameter resolution on computational efficiency, the available literature lacks a systematic investigation that evaluates the impact of key input variables. This gap highlights the need for a structured analysis to guide effective modelling creation in practical applications. This paper is part of a broader research initiative that systematically evaluates the impact of input parameter resolution on computational efficiency in environmental noise modelling across different project scales, complexity levels, and two widely used noise prediction software packages, SoundPLAN and CadnaA. The current work represents the first phase of this investigation and focuses exclusively on the use of SoundPLAN for a single, representative

project. By analysing how changes in key input parameters affect both model execution time and prediction performance, this study seeks to identify practical trade-offs that can inform efficient modelling practices. The findings are intended to support practitioners in selecting parameter configurations that maintain reliable accuracy while optimizing computational demands, particularly in time-sensitive or resource-constrained projects.

2 METHODS

The present environmental noise modelling study was conducted using SoundPLAN version 9.0 by implementing RLS 90 (Richtlinien für den Lärmschutz an Straßen -1990) model for road traffic and Schall 03: 1990 for rail noise on a high-performance modelling workstation. QGIS (Quantum Geographic Information System) was used to assist in the development of the base model by defining the topographical context of the project area. The system was equipped with an Intel Xeon w9-3495X CPU with 56 cores, 112 threads, a 105 MB cache, an NVIDIA RTX A2000 GPU, and 256 GB of RAM. This setup ensured consistent and reliable performance for evaluating the computational impact of varying input parameter resolutions.

2.1 Case Study

The case study selected for this investigation is located within the Chatswood commercial precinct, a major urban hub on Sydney's North Shore. The site is positioned near Chatswood Railway Station and to the east of Pacific Highway. The site is surrounded by a dense mix of commercial, residential, and institutional buildings that present typical urban acoustic challenges. The original project design featured two 25-storey high-rise towers connected by a common podium. Preliminary modelling indicated that simulating both full-height towers under high building complexity scenarios led to excessively long computation times, making it impractical to carry out a systematic analysis across multiple test cases. To maintain computational feasibility while preserving realistic complexity, the main building model was adjusted to represent a single tower with ten storeys. This reduced form allowed for consistent processing of all test scenarios within a manageable time frame while still retaining the architectural scale and urban context.

2.2 Model Input Parameters

Five input parameters were selected for study at two levels, designated as low (-1) and high (+1), to assess how their resolution influenced the computational efficiency of façade noise mapping. Table 1 outlines the five input parameters. The selected parameters include: Main Building Complexity (A), which varied between a simplified building geometry and a detailed representation that included façade elements and balconies; Reflection Order (B), tested at 3rd order for the low level and 5th order for the high level; Surrounding Buildings Density (C), defined as low density (a single row of adjacent buildings) and high density (all existing buildings within an approximate 500-meter radius); Ground Absorption (D) was set to a generic value of 0.5 at the low level, while the high level included separate ground absorption zone (0.9) for vegetation and tree-covered areas. It is understood that due to site specific limitations (vegetation zone doesn't lie between source and receiver), the impact of ground absorption was only applicable to computation time. Extent of Noise Source (E) represented line sources such as road and rail corridors, with the short line source defined by the line-of-sight (LoS) from the building façade at ground level, and the long line source set to twice the LoS. Figure 1 illustrates the ground absorption zones and LoS criteria on aerial imagery.

Table 1: Selected input parameters with respective levels

Input Parameter	Code	Low Level (-1)	High Level (+1)
Main Building Complexity	A	Low	High
Reflection Order	B	3 rd order	5 th order
Surrounding Buildings Density	C	Low density	High density
Ground Absorption (GA)	D	Generic	Detailed
Extent of noise source	E	Short (LoS)	Long (2x LoS)



Figure 1: Markup for ground absorption and LoS criteria

2.3 Design Matrix

The modelling test scenarios were developed using a design of experiments (DoE) approach (Antony 2023). A fractional factorial design was employed to construct the design matrix, allowing efficient evaluation of the main effects of five input parameters while minimizing the total number of simulations required. This method ensured systematic variation of parameters and reliable assessment of their individual influence on computational performance.

A 2^{5-2} fractional factorial design was used to reduce the total number of modelling runs to eight, as presented in Table 2. The first three factors, namely Main Building Complexity (A), Reflection Order (B), and Surrounding Building Density (C), were selected as the base variables, resulting in eight test combinations. The remaining two factors, Ground Absorption (D) and Extent of Noise Source (E), were deliberately confounded with multifactor interactions to reduce the number of test iterations. D was confounded with the interaction of B and C ($D = BC$), and E was confounded with the interaction of A, B, and C ($E = ABC$).

Table 2: Design matrix

Test run	A	B	C	D=BC	E=ABC
1	-1	-1	-1	+1	-1
2	+1	-1	-1	+1	+1
3	-1	+1	-1	-1	+1
4	+1	+1	-1	-1	-1
5	-1	-1	+1	-1	+1
6	+1	-1	+1	-1	-1
7	-1	+1	+1	+1	-1
8	+1	+1	+1	+1	+1

2.4 Modelling Test Scenarios

Table 3 presents the eight modelling test configurations derived from the design of experiments matrix. For each run, façade noise mapping was conducted to determine sound pressure levels across all building façades at each floor level.

Table 3: Modelling test scenarios

Test run	Main Building Complexity	Reflection Order	Surrounding Buildings Density	Ground Absorption	Extent of noise source
1	Low	3 rd order	Low density	Detailed GA	Short (LoS)
2	High	3 rd order	Low density	Detailed GA	Long (2x LoS)
3	Low	5 th order	Low density	Generic GA	Long (2x LoS)
4	High	5 th order	Low density	Generic GA	Short (LoS)
5	Low	3 rd order	High density	Generic GA	Long (2x LoS)
6	High	3 rd order	High density	Generic GA	Short (LoS)
7	Low	5 th order	High density	Detailed GA	Short (LoS)
8	High	5 th order	High density	Detailed GA	Long (2x LoS)

The simplest and most complex modelling scenarios, corresponding to Test Run 1 and Test Run 8 respectively, are illustrated in Figure 2. These views highlight the variation in input conditions, including differences in building complexity, surrounding building density and other selected input parameters, demonstrating the range of configurations assessed in the study.

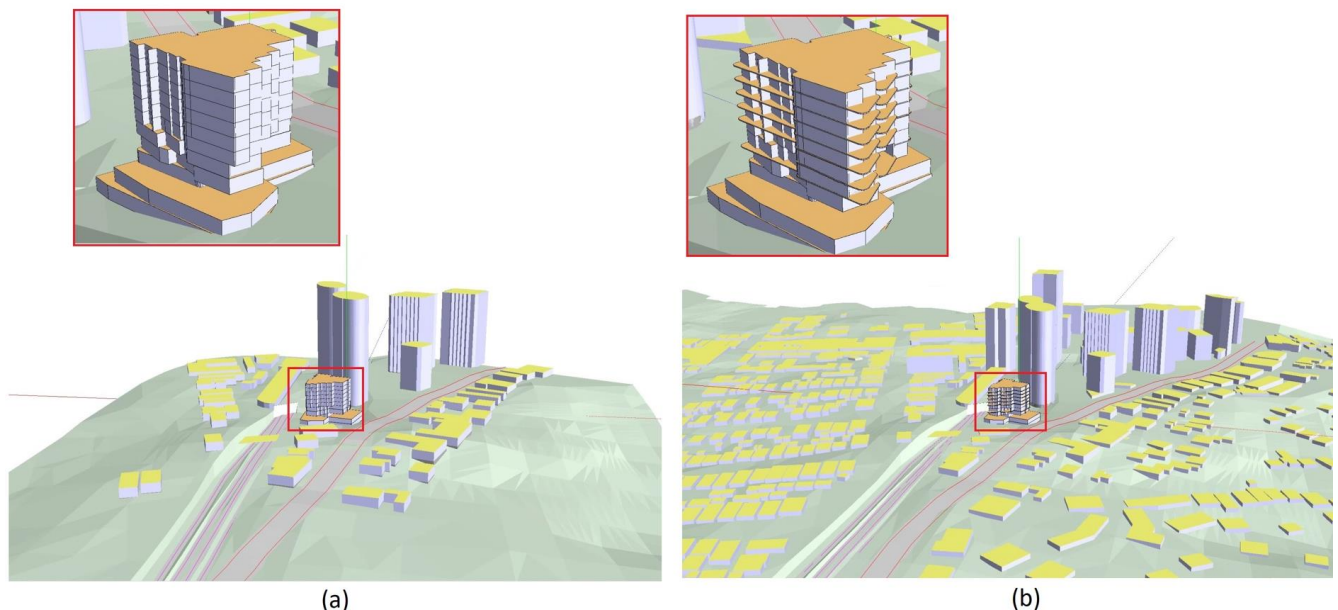


Figure 2: 3D views of the modeling test scenarios: (a) Test Run 1, (b) Test Run 8

2.5 Modelling Outputs of Interest

Two key outputs of the modelling were of focus for this investigation: computation time, and relative accuracy of the façade noise map results.

As the modelling results for façade sound pressure were not calibrated against any measured data, the model scenario with the most detailed inputs (Test Run 8) was adopted as the benchmark for maximum prediction accuracy.

To facilitate quantitative comparison across all modelling test runs, the accuracy of predicted façade noise levels was expressed in terms of relative deviation, measured in decibels (dB) with respect to the benchmark. Test Run 8 was assumed to represent 100% accuracy and was therefore assigned a reference error value of 0 dB. The

remaining test runs were evaluated by calculating the deviation of their predicted results from this benchmark, allowing for a consistent assessment of relative accuracy.

2.6 Calculation Of Variable Influence

The influence of each input variable on the output response was determined using the standard method from DOE, based on the difference between the arithmetic average results at the high (+1) and low (−1) levels of each variable. The influence of a variable X is expressed as:

$$I_X = \bar{Y}_{\text{high}} - \bar{Y}_{\text{low}} \quad (1)$$

where I_X represents the influence of variable X , $\bar{Y}_{\text{high}}$ is the mean response (computational time or prediction accuracy) from all runs where X was at its high level (+1), and $\bar{Y}_{\text{low}}$ is the mean response where X was at its low level (−1).

For example, the influence of variable A was calculated as:

$$I_A = \frac{Y_2 + Y_4 + Y_6 + Y_8}{4} - \frac{Y_1 + Y_3 + Y_5 + Y_7}{4} \quad (2)$$

where Y_i denotes the output response for the i^{th} test run. A positive influence value indicates that the variable's high level increases the response value, while a negative value indicates a reduction in the response. This method was applied to all primary variables and interaction terms to quantify their relative effects on both computational time and relative accuracy.

3 RESULTS & DISCUSSION

Table 4 summarises the computational time and relative prediction accuracy for each modelling test run, based on the defined input parameter configurations.

Table 4: Computational Time and Prediction Accuracy results

Test run	Computational Time	Relative Accuracy (max. deviation)
1	7 mins	9 dB
2	49 mins	1 dB
3	29 mins	9 dB
4	3 hr 54 mins	1 dB
5	14 mins	9 dB
6	1 hr 12 min	1 dB
7	44 mins	9 dB
8	7 hr 30 mins	Benchmark case

3.1 Computational Time

The influence of each variable on computational time is presented in Figure 3 below.

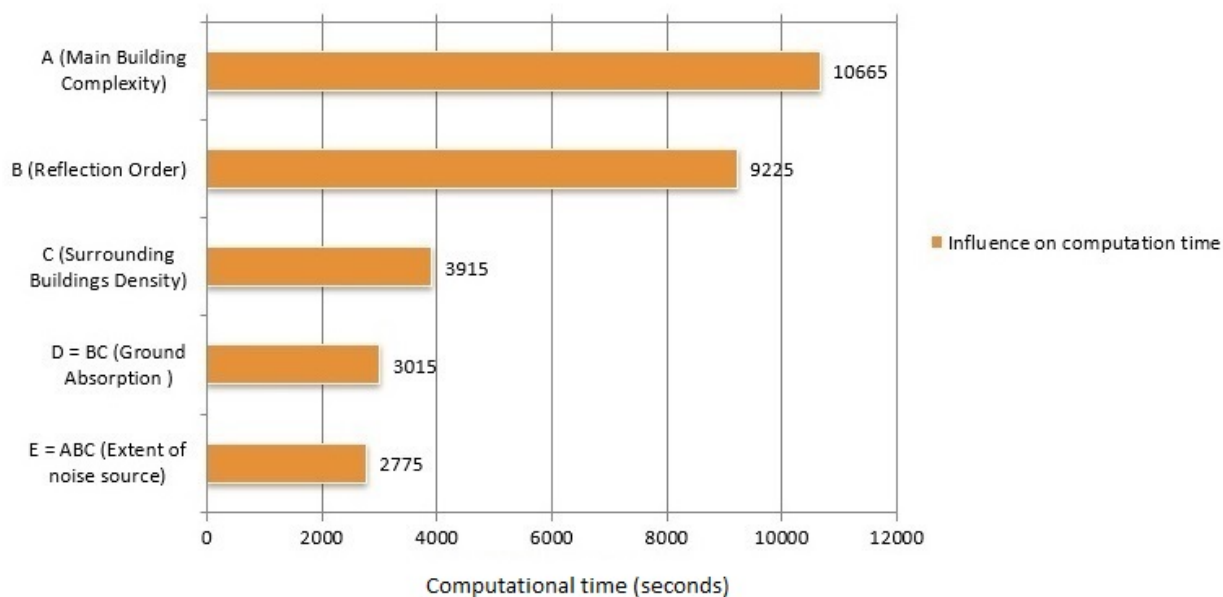


Figure 3: Influence of variables on computational time

The DOE analysis indicates that the main building complexity and reflection order were the primary determinants of computational time. The geometric detail of the subject building and higher reflection orders substantially increase the number of acoustic rays and reflection paths that must be resolved within the simulation. Consequently, models featuring detailed building façades or higher-order reflections demand significantly longer computation times.

The surrounding building density exhibited a moderate influence, suggesting that environmental context, while relevant, imposes a smaller computational burden compared to the main building geometry or acoustic reflection complexity. Similarly, the ground absorption (D) and extent of noise source (E), which are confounded with the multivariable interactions, showed a limited impact on the computation time.

3.2 Relative Accuracy

Figure 3 presents the influence of input variables on the relative accuracy of the resulting façade noise maps, expressed as deviation in decibels (dB) from the benchmark sound pressure levels from Test Run 8.

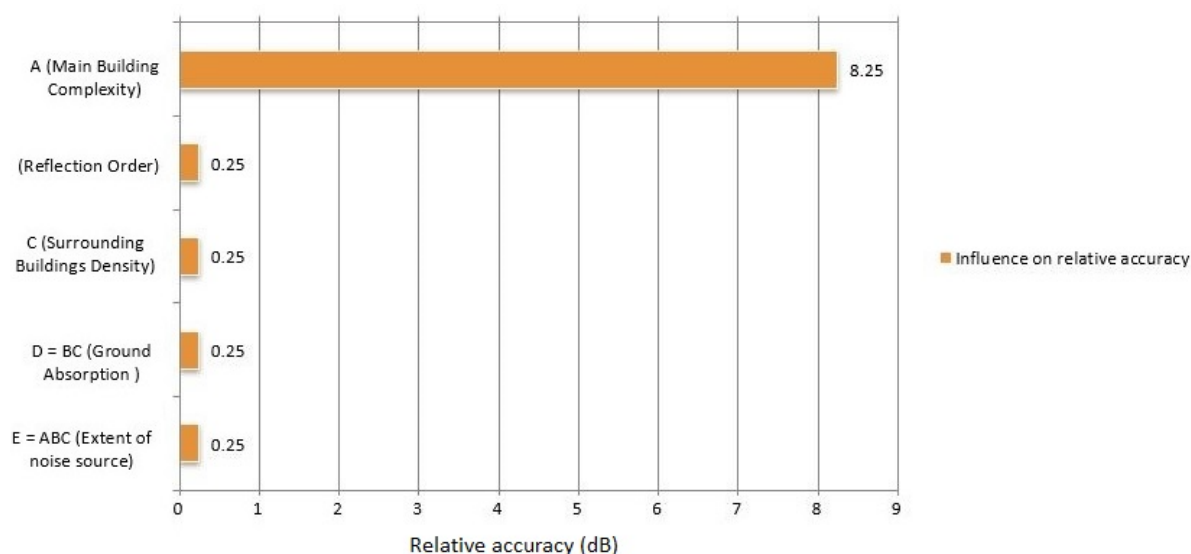


Figure 4: Influence of variables on relative accuracy

The analysis identifies that main building complexity presents the dominant variable influencing relative accuracy of the output façade sound pressure levels, with a difference of approximately 8 dB between the low and high input levels, with the simpler building geometry predicting higher noise exposure values. This outcome clearly suggests that façade geometric details significantly impact the reliability of noise predictions, as complex geometries allow a more realistic representation of sound reflections and façade exposure conditions.

Other factors, including reflection order, surrounding building density, and the interaction terms $D = BC$ and $E = ABC$, exhibited negligible influence on prediction accuracy. This indicates that once an adequate reflection order is incorporated, further increases produce diminishing returns in predictive performance. Similarly, variations in environmental density or combined effects of variables had minimal impact on the overall relative accuracy of façade sound level prediction.

Further spatial examination of façade receivers showed that the 9 dB difference was primarily observed at the Northern and Eastern receivers, while the Southern and Western receivers exhibited smaller differences ranging between 3 and 6 dB. This variation can be attributed to the site's acoustic context, where the railway corridor located east of the site acts as a dominant noise source, directly exposing the eastern façades to higher sound pressure levels. Additionally, the absence of surrounding buildings to the north allows unobstructed propagation of acoustic rays, intensifying the effect of façade geometry and modelling detail on the predicted noise levels.

To further examine the notable difference in relative accuracy and review the contribution of individual noise sources, a receiver exhibiting a 9 dB deviation between the low and high building complexity cases was selected. A separate single-point (at the eastern façade, Level 10) noise prediction was then carried out for Test Runs 1 and 8 and results. Table 5 below presents the relative source contributions and Figure 4 shows the receiver position and difference in the building geometric complexity.

Table 5: Single point receiver results

Receiver details	Source	Source type	LrD (dBA)	
			Run 8	Run 1
Floor level: 10 Orientation: East	Pacific Hwy	Road, L	38.6	39.3
	Rail – Northbound	Railway	52.9	64.1
	Rail – Southbound	Railway	57.7	65.6
	Metro – Northbound	Railway	54.3	65.9
	Metro – Southbound	Railway	56.0	65.8
	Pacific Hwy	Road, R	38.7	39.6
			61.7	71.4

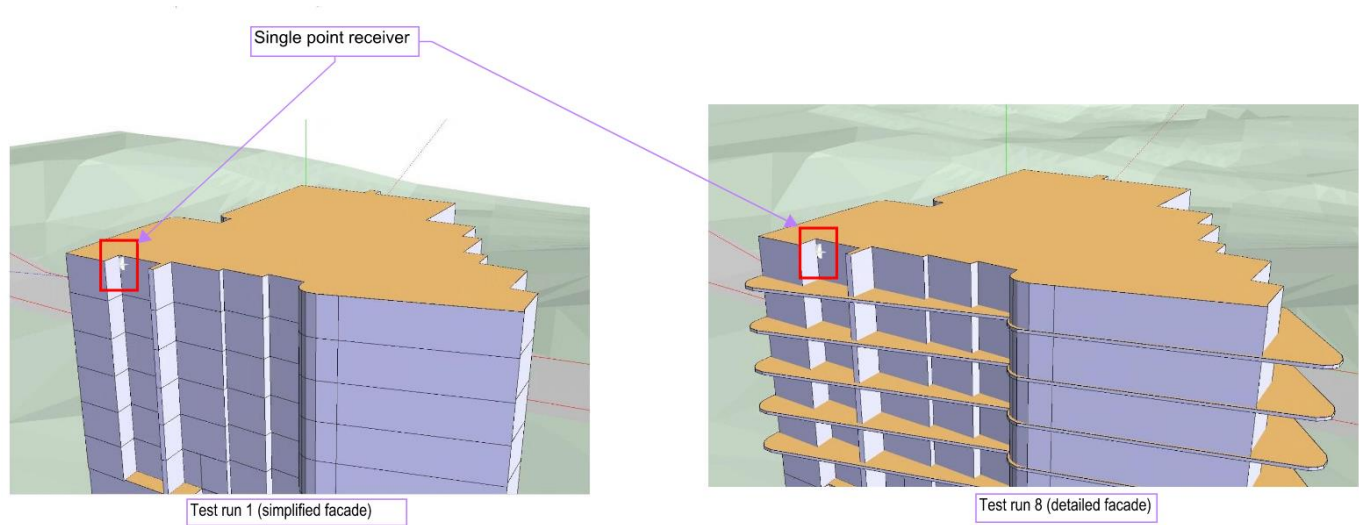


Figure 5: Single point receiver location and building facade details

It is clear from Table 5 that predicted rail noise contributions were considerably higher in Run 1 compared with Run 8, primarily due to differences in façade geometry. Run 1 utilised a simplified façade configuration, whereas Run 8 included detailed balcony structures. Since the railway tracks are positioned below and directly face the eastern balconies, the inclusion of balconies in Run 8 introduced a shielding effect that attenuated direct line-of-sight exposure from the rail sources. Moreover, this difference in predicted levels between Run 8 and Run 1 gradually decreased with lower floors and became negligible below Level 4. These findings indicate that simplified façade geometries can substantially overestimate façade noise exposure, particularly for receivers oriented toward dominant line sources such as rail corridors.

A comparative assessment of all the modelling scenarios highlights the trade-off between computational cost and predictive performance. Although the most detailed configuration (Run 8) regarded with benchmark accuracy, it required a computational time exceeding seven hours. In contrast, Run 2, which used a higher main building detail but a lower reflection order and reduced surrounding complexity, achieved the same prediction accuracy with a computational time of under 1 hour. This finding demonstrates that an increase in model resolution does not necessarily yield a proportional difference in accuracy once the essential acoustic characteristics of the environment are adequately captured.

The results indicate that beyond a certain level of input detail, further increases in geometric and acoustic resolution greatly extend computational time without significantly improving the reliability of predicted façade sound levels. Simplified models with moderate detail achieved accuracy comparable to high-resolution configurations, highlighting a point of diminishing returns. An effective modelling strategy can therefore balance geometric detail, reflection order, and environmental complexity to optimise both efficiency and accuracy.

4 CONCLUSIONS

This study evaluated the influence of key input parameters on computational time and relative accuracy in façade noise mapping. The analysis revealed that main building facade detail and reflection order, were the dominant factors influencing computational time, while main building complexity alone had a significant effect on relative prediction accuracy. Spatial analysis showed that façades directly exposed to dominant noise sources were more sensitive to modelling detail, whereas shielded façades exhibited minimal variation.

Overall, the results highlight a clear trade-off between model resolution and computational cost. Achieving an effective balance between input detail and computational efficiency is essential for producing reliable and practical environmental noise predictions.

5 FUTURE WORK RECOMMENDATIONS

This study represents the first phase of a broader investigation into how input parameter resolution affects computational efficiency and prediction accuracy in façade noise mapping. Future research is required to extend the analysis to different project scales and geometric complexities to verify whether the observed trade-offs remain consistent across various urban contexts. Comparative modelling using SoundPLAN and CadnaA is also recommended to examine how algorithmic and computational differences influence model performance.

Further work is warranted to explore the spatial sensitivity of prediction accuracy by considering different receiver orientations, shielding conditions, and dominant noise sources. In addition to this, impact of prioritising high-resolution modelling for exposed façades or critical assessment areas and keeping simplified configurations to shielded façades and larger-scale analyses, needs to be investigated. These investigations will support the development of practical modelling guidelines that can optimise input detail according to project objectives, site characteristics, and available computational resources.

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