Fairly assigning noise emission limits to new industrial precincts

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Abstract – New industrial or expansion of existing industrial precincts offer unique challenges to planners and developers. One of the challenges related to noise is how to fairly assign noise emission limits to sites in the precinct without knowing how the rest of the precinct will be developed. EMM Consulting Pty Limited has gained experience in preparing assessments for projects involving planning for future land use. This paper will describe three methods we have used for assessing industrial precincts. The first is a reverse modelling technique, where sources are placed on receivers around the precinct and noise contours are generated inside the precinct. The second method is to generate a risk map within the precinct using a grid of source points. The final method uses a developer's concept or master plan to determine noise allocation goals for the individual lots within the site.

1 INTRODUCTION

The New South Wales Environment Protection Authority (EPA) created the Noise Policy for Industry (NPfI) (NSW EPA, 2017). Its purpose is to ensure that noise from industrial developments are assessed and managed consistently. Typically, industrial sites are assessed on an individual and case by case basis, which forms that focus of the NPfI.

It also defines a procedure for assessment of expansion of an existing or new industrial precincts, comprising multiple noise generating lots, as a single site. This allows lots within a precinct to work with one another to achieve defined cumulative noise levels at receivers. The procedure's objective is to efficiently develop the site while maintaining the noise amenity at neighbouring receivers established in accordance with the NPfI.

The policy doesn't give detailed guidance how to allocate noise goals to individual lots. The method given in the NPfI is only based on the number of sites affecting a receiver. However, this does not account for the size of the lot, distance or likely acoustic shielding to receivers and assumes equal noise contribution from all lots.

This paper describes three methods to help in the planning stages of a precinct. The first two methods, reverse modelling and risk mapping, are useful to evaluate a parcel of land to determine what type of industry is appropriate based on typical noise emissions and assist in developing a use strategy for a precinct.

The third method, conceptual noise allocation modelling, is useful when a concept or master plan has been developed. It is used to determine noise allocations for individual lots to representative assessment locations to ensure cumulative levels comply with project amenity levels, based on an indicative site sound power and areas of the lot relative to the precinct. The noise allowance is given as a maximum L_{Aeq} level a lot can contribute at a receiver.

The results of worked examples for each method are presented, showing the information each approach provides.

Following the worked examples, strengths and weaknesses of each method are discussed.

Finally, concluding remarks are provided.

2 METHODS FOR FAIRLY ASSIGNING NOISE GOALS

There are three steps an area of land goes through before it is developed into an industrial precinct; first the area is identified for possible development (either already zoned and permissible for proposed use or subject to a rezoning process occurring to support the use), then a concept or master plan is created for the area; and finally a detailed plan for a lot is made and assessed.

Reverse modelling and risk maps are tools to help assess the suitability of an area of land for industrial use by identifying how much of the land can be used for different noise generating activities. These can be valuable from a risk analysis perspective or to inform a rezoning of a new green or brownfield site.

Following the concept or master plan, conceptual noise allocation modelling is used to define goals for the lots inside the site. These goals will be used in a detailed noise model in the approval stage of the development.

2.1 Reverse modelling

Reverse modelling generates a contour map of the precinct showing where different types of industry can be placed, depending on how much noise they are expected to generate.

The map is created by placing noise sources on each of the most affected receivers around the precinct. The sound power of the sources are set to typical levels generated by the type of industry expected to be found in the precinct.

A grid of points is generated inside the precinct, and noise levels are calculated to each point. The calculated levels are used to generate a contour map of the precinct.

The contour thresholds should be set to the criterion of the receivers.

2.2 Risk mapping

Risk maps are a more flexible method than reverse modelling to determine where noisy activities can be placed in a precinct.

A grid of source points are generated within the precinct. Subject to the size of the precinct being mapped, grid spacing may vary from 10 up to $100\,\mathrm{m}$. The sound power of the source point is arbitrary, e.g. $110\,\mathrm{dB}$.

Levels are calculated at receiver points around the precinct. The difference between the receiver noise level and the source sound power is the *transfer function* from source to receiver.

Using the transfer functions, H_{ij} from source i to receiver j, and the receiver's criterion, C_j, a maximum allowable sound power for each source point for the receiver, L_{Wij}, can be calculated:

$$L_{Wij} = C_j + \Delta_{Hij} + H_{ji}\,\mathrm{dB}. \tag{1}$$

Δ_{Hij} is a coefficient that determines a fair contribution at the receiver from each source point. Calculating this coefficient is discussed in Subsection 3.2.

This is repeated for each receiver, and the overall maximum allowable sound power for a source, L_{Wi} is calculated as the minimum of the set of sound powers L_{Wij}, or:

$$L_{Wi} = \min\{L_{Wij}\}\ \mathrm{dB}. \tag{2}$$

Receiver levels are calculated using these sound powers. Because the source sound power is the minimum of all sound powers, the resulting levels at the receivers are going to be less than or equal to their criterion.

Where the calculated level is less than the receiver's criterion, its target level is increased, and the process is repeated to find the maximum allowable sound power for each source point.

An optimisation algorithm is used to minimise the difference between a receiver's actual criterion and the resulting predicted level, by adjusting the receiver's target level.

The maximum allowable sound power is converted to a sound power density, I_{Wi} by dividing the total precinct area, A, by the number of source points, N, and subtracting $10\log_{10}$ of the ratio from the sound power, L_{Wi}, or:

$$I_{Wi} = L_{Wi} - 10\log_{10}\left(\frac{A}{N}\right)\ \mathrm{dB/m^2}. \tag{3}$$

The resultant sound power density grid points were used to generate a contour map inside the precinct.

The thresholds of the contours are based on the expected type of industry to be found in the precinct.

The areas of risk indicate what industry can likely be supported and anticipated mitigation.

2.3 Conceptual noise allocation modelling

Conceptual noise allocation modelling is the final step before a detailed impact assessment for a precinct or lot is undertaken. Here a concept or master plan, which includes indicative locations of warehouses, hardstands and loading docks, and sizes of lots, is assessed to determine a noise goal allocation for each lot.

A noise lot allocation sets the maximum allowable L_{Aeq} noise level contribution a lot can have at a receiver to ensure the total cumulative level at the receiver from all lots meets the receiver's criterion. This is subsequently repeated for all receivers to determine noise allowances for various noise catchment areas surrounding a precinct.

The NPfI (NSW EPA, 2017) provides a method for calculating a noise goal for multiple noise generating premises for an intensification of an existing industrial precinct or a new green field industrial precinct:

$$\text{IPANL} = 10\log_{10}\left(\frac{10^{(\text{ANL}-5\,\text{dB})/10}}{N}\right)\ \text{dB}, \tag{4}$$

where IPANL is the individual project amenity noise level at the receiver, N is the number of new premises, and ANL is the amenity noise level of the receiver. The amenity level is corrected by 5 dB to account for contributions from other industrial premises.

This simple method doesn't account for the size of the new premises in relation to each other or the total precinct, nor does it account for any losses in the noise propagation path from the premise to the receiver.

A fair target level, IPANL, for a lot i in a site should take the form of:

$$\text{IPANL}_i = C + \Delta_i\,\text{dB}, \tag{5}$$

where C is the criterion at the receiver and Δ_i is a correction that accounts for the area of the lot relative to the precinct and the transfer function (acoustic losses from distance and shielding) from the lot to receiver.

The correction is subject to the constraint:

$$10\log_{10}\sum_{i}^{N}10^{\frac{\Delta_i}{10}} = 0\,\text{dB}, \tag{6}$$

or, the logarithmic sum of all corrections must be $0\,\text{dB}$.

The noise allocation level will be used in an assessment of the individual lot as a design goal, to determine the mitigation measures required.

This section described three methodologies for assessing an industrial precinct from the planning stage, using reverse modelling and risk mapping, to the pre-development stage using a noise allocation model based on a concept or master plan.

Noise allocation models and risk maps require corrections to the receiver's criterion to fairly assign a noise goal for a lot to ensure cumulative noise meets the overall noise goal for the precinct. The next section will describe how to calculate these corrections.

3 TARGET LEVEL CORRECTIONS

The risk maps and allocation noise models require an adjustment for each source to the receiver's criterion to determine an equitable noise level contribution at the receiver. This adjustment is based on the area represented by the source and noise propagation losses from the source to receiver.

For the risk map, each source represents the same amount of area, so the area correction can be ignored.

3.1 Area correction

A lot's contribution to a receiver noise level from the site should be proportional to the ratio of the lot's area to the total developable area of the precinct.

The area correction, Δ_{Ai} , can be calculated as:

$$\Delta_{Ai} = 10\log_{10}\left(\frac{A_i}{A}\right)\ \text{dB}, \tag{7}$$

where A_i is the area of lot i and A is the total developable area of the precinct.

If only a lot's area is considered when determining a noise allowance, there is a risk the site will be developed inappropriately. For example, a lot with a large area in relation to the total precinct's area and well separated from the nearest receiver. This lot will be given a high relative noise allowance but does not consider significant attenuation that may be present due to propagation effects and shielding resulting in a low actual noise level at a receiver, and its allowance could feasibly be higher. Contrary, a similarly large site at the boundary of a precinct would be granted a similar allowance but have limited noise attenuation due to distance and constrained abilities to provide acoustic shielding, resulting in excessive noise levels at the receiver.

3.2 Transfer function correction

To equitably determine a lot's contribution to the receiver's level, the transfer function from lot to receiver should be considered.

The transfer function from a lot can be found by placing a point or area source, with an arbitrary sound power, on the lot and use a noise model to calculate a level at the receiver. The transfer function is the difference between the sound power and the calculated level at the receiver. The selection and location of a point or area sources should be considered carefully to ensure the outputs are not adversely skewed favouring a shielded or non-shielded source location.

Once the transfer function from each lot is determined, then the transfer function needs to be normalised to:

$$\hat{H}_i = \frac{\max(\mathbf{H}) - H_i}{\max(\mathbf{H}) - \min(\mathbf{H})}, \tag{8}$$

where $\mathbf{H}$ is the set of all the lots transfer functions. H_i is the transfer function from lot i to the receiver, and $\hat{H}_i$ is the normalised transfer function. The transfer function from a lot to a receiver is the total noise propagation loss, e.g. due to geometric spreading.

Subtracting a single lot transfer function from the maximum of all lots transfer functions means lots with greater attenuation should have lower allowance at the receiver.

The correction due to transfer function, Δ_{H_i}, at lot i is:

$$\Delta_{H_i} = 10\log_{10}\frac{\hat{H}_i}{\sum\hat{\mathbf{H}}}\,\mathrm{dB}. \tag{9}$$

Here $\sum\hat{\mathbf{H}}$ is the sum of each lot's normalised transfer function, or

$$\sum\hat{\mathbf{H}} = \sum_{i=1}^{N}\hat{H}_i. \tag{10}$$

Again, if only the transfer function is considered, then sites further from the receiver will be provided greater noise lot allowances regardless of the lot's area. This potentially constrains large lots or provides smaller lots with noise allowances higher than they would in practice capable of generating when assessed to receiver.

3.3 Combining corrections

The two corrections need to be combined to fairly determine a noise goal:

$$\Delta_i = 10\log_{10}\left(k\frac{A_i}{A} + (1-k)\frac{\hat{H}_i}{\sum\hat{\mathbf{H}}}\right)\mathrm{dB}. \tag{11}$$

Where k is a value between 0 and 1, and can be optimised depending on the intent of the precinct development.

One approach may be to provide the greatest noise allowances to a key number of lots within a precinct to accommodate a known or likely tenant, this optimises the noise allocations for those lots. Remaining lots are provided with lower noise lot allowances and subsequent capability of lower intensity activities or requirement for increased provision of mitigation to meet receiver noise levels.

Alternatively, the approach may be to provide an equivalent distribution of noise allowances based on the area and transfer functions to allow maximum flexibility for all lots.

Using the corrections described in this section, worked examples for the three methods will be discussed in the next section.

4 WORKED EXAMPLE

The previous section discussed methods for equitably assigning noise goals to lots in an industrial precinct. This section will give an example of each method in assessing a precinct.

The three examples are based on the same area, shown in Figure 1. This area is loosely based on an actual industrial site to ensure lot and building sizes are realistic.

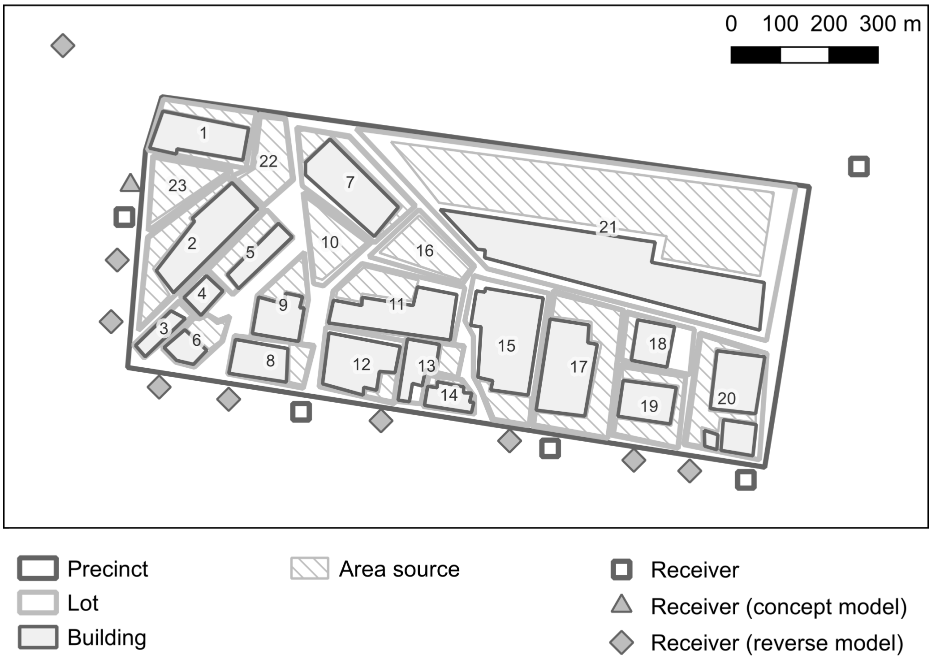

Figure 1: The base scenario used in the three examples. The precinct outline is used to generate the contours in the reverse model and the risk map. The reverse model only uses the square receivers, the conceptual noise allocation model shows results for the triangle receiver, and the risk map uses all receivers. The conceptual noise allocation model also uses the area sources, building layouts, and lots sizes.

Levels were calculated at receiver positions with *iNoise 2024.1* (DGMR Software, 2024) using the ISO 9613-2:1996 (International Organization for Standardization, 1996) algorithm and the total sound power at $500\,\mathrm{Hz}$.

The reverse model and risk map use a ground factor of $G = 1.0$, representing soft ground. And the precinct is modelled as an industrial site with an attenuation coefficient of $0.025\,\mathrm{dB/m}$. These two adjustments were used as a conservative estimate of screening effects expected in a real industrial site.

The strategic noise model was created using $15\,\mathrm{m}$ high buildings and a ground factor of $G = 0$ inside the precinct and 0.7 outside.

4.1 Reverse model

The reverse model was created by placing a noise source at each of the receiver locations. Each source point was modelled with a sound power of $110\,\mathrm{dB(A)}$. This represents a typical sound power used to model a hardstand in a distribution warehouse and would be considered conservative (high).

The contours for the reverse model are shown in Figure 2. The first contour threshold is $35\,\mathrm{dB}$, which is the minimum threshold under the NPfI. The next two contour thresholds are 3 and $6\,\mathrm{dB}$ lower, representing a doubling of allowable energy in each area.

The significance of the contour lines is if a noise source with a sound power of $110\,\mathrm{dB(A)}$ is placed on the contour, then the maximum level at any of the receivers will be the value of the contour line. For example, if the source is placed on the $35\,\mathrm{dB(A)}$ contour, then the maximum level at any of the receivers will be $35\,\mathrm{dB(A)}$.

4.2 Risk map

A risk map of the precinct, shown in Figure 3, was generated by creating a grid of $20 \times 20\,\mathrm{m}^2$ spacing of noise sources within the precinct. Levels were calculated from source to receiver using ISO 9613-2:1996.

The method described in Subsection 2.2 was used to find the maximum allowable sound power for each source.

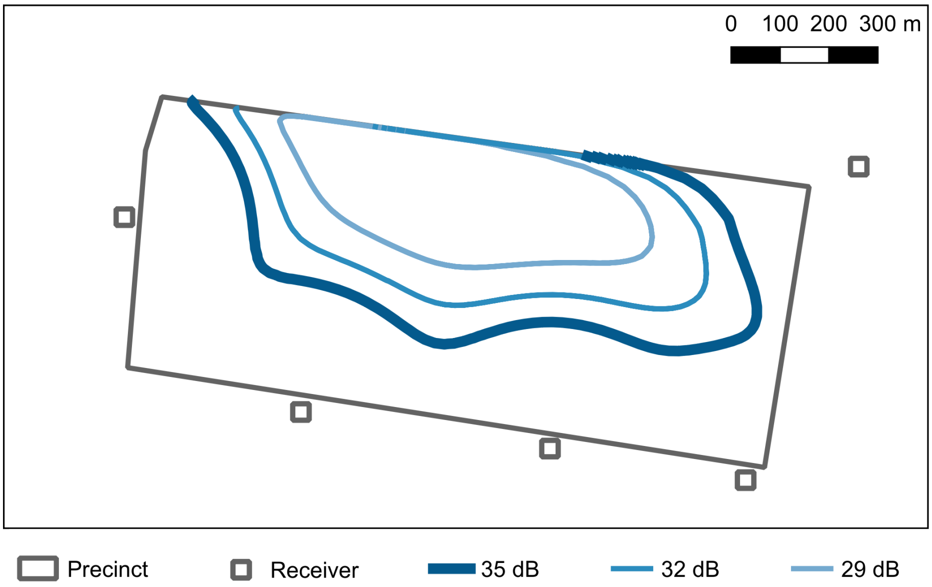

Figure 2: Contours generated from the reverse model. The thresholds of the contours are based on the expected type of industry to be found in the precinct.

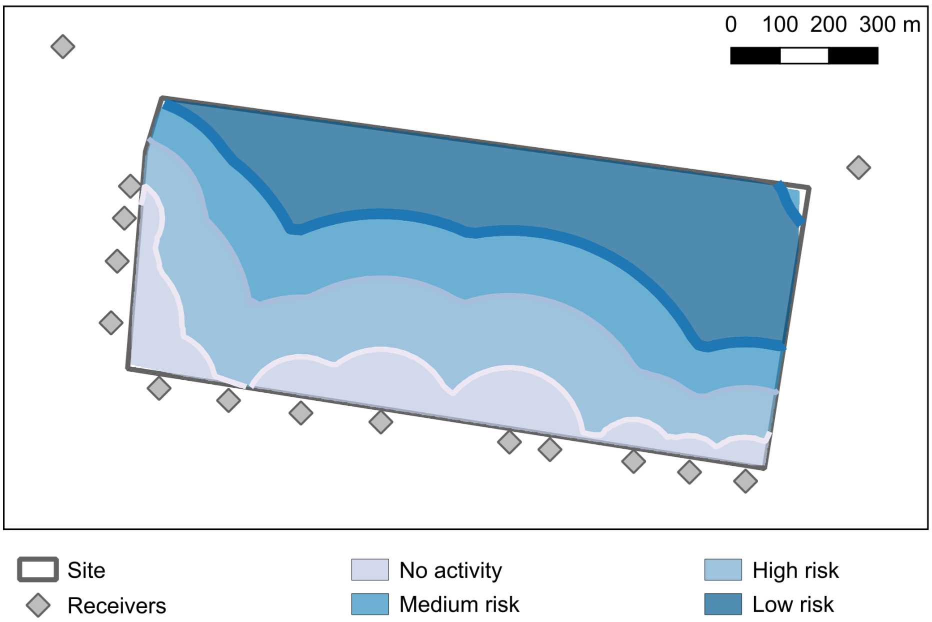

Figure 3: An example of a risk map showing areas of different risk. The areas of risk indicate what industry can likely be supported and anticipated mitigation.

Sound power density was calculated by subtracting $10 \cdot log_{10}\left(\frac{A}{N}\right)\,\mathrm{dB}$ from the sound power of each source, with A the total precinct area and N is the number of sources. Triangulated Irregular Network (TIN) interpolation was used to create a raster map of the densities in the precinct, and r.contour (GRASS Development Team, 2024) was used to create contours from the raster.

The thresholds were based on EU's Good Practice Guide for Strategic Noise Mapping's (WG-AEN, 2006) and a typical sound power density of $50\,\mathrm{dB/m^2}$ for distribution centres.

The precinct is divided into 4 areas of low, medium, and high risk and areas where no activity can occur. The risk levels are based on how much mitigation is required for a given activity to operate in the area.

The low risk threshold was set to $38\,\mathrm{dB/m^2}$, which is based on assumed screening from warehouses of $10\,\mathrm{dB}$ and $2\,\mathrm{dB}$ to account for operations not occurring simultaneously all the time. Minimal mitigation is likely to be needed by distribution centres located in low risk areas.

The threshold separating low and medium risk areas is $35\,\mathrm{dB/m^2}$, which represents double the energy of low risk activities. Distribution centres in this area are likely to require some mitigation measures, such as barriers.

The threshold for limited or no activity is $30\,\mathrm{dB/m^2}$, which is $20\,\mathrm{dB}$ below the typical sound power density. This is the maximum achievable reduction with standard mitigation measures (Standards Australia, 2010). For example, a warehouse with commercial office that ceases logistics in evening and night but may have a call centre and light vehicles 24/7.

4.3 Concept noise allocation model

A concept noise model of the area was created using the location of buildings and noise generating areas. Where the area is large, with respect to the lot, an area instead of point source should be used. This model considered areas sources.

Levels were calculated to each receiver using an area source and arbitrary $110\,\mathrm{dB}$ total sound power for each lot. The difference between the sound power and the predicted level gives the transfer function for lot to receiver.

Using the methods described in Section 3, an allowance for each lot at each receiver was calculated. Table 1 shows the allowance for one receiver (R1, shown as a triangle in Figure 1) for all 23 lots. The table also gives the NPfI allowance, area per lot, area ratio, transfer function, transfer function ratio and adjusted lot allowance.

The NPfI goal is determined using the method outlined in Section 2.4.2 of the NPfI and applied based on a 23 lot precinct as used in this worked example considering minimum night project amenity of $35\,\mathrm{dB}$ (ANL $40\,\mathrm{dB} - 5\,\mathrm{dB}$). Applying the NPfI coarse method results in an allowance of $L_{Aeq}\ 21\,\mathrm{dB}$ for a single lot. The NPfI method assumes equal contribution from all lots.

The transfer function is based on the calculated level at the receiver (R1) from the concept model, the TF ratio is calculated using *normalised* transfer function (see Section 3.2).

The adjusted lot allowance column gives the goals for each lot at R1 taking into account area and transfer function with an assumed k factor of 0.5 - which is an equal weighting of area and transfer functions.

Using lot 1 as an example,

$$\Delta_i = 10\log_{10}\left(k\frac{A_i}{A} + (1-k)\frac{\hat{H}_i}{\sum\hat{\mathbf{H}}}\right) \quad \mathrm{dB} \tag{12}$$

$$= 10\log_{10}(0.5\cdot 0.04 + 0.5\cdot 0.11) \quad \mathrm{dB} \tag{13}$$

$$= -11 \quad \mathrm{dB}. \tag{14}$$

Adding the correction, Δ_i, to the receiver's night project amenity of $35\,\mathrm{dB}$ gives an allowance of $24\,\mathrm{dB}$.

5 DISCUSSION

The reverse model is a useful first step in analysing an area of land to determine its suitability for industrial use. Contours can easily be generated with commercial noise prediction software without any post-processing. It is particularly suitable in large green field areas where the proposed industrial precinct boundaries may not yet be defined, but existing sensitive receivers are identified. The reverse model is most useful in rural areas with a few isolated receivers.

However, there is an implicit requirement that a lot in the area is the only noise source dominating the noise level at a single receiver.

Table 1: Noise goals $L_{Aeq,period}$ for a single receiver (R1) from all lots (23). The maximum and minium transfer functions have been highlighted.

Lot No	NPfI Allowance	Area (m^2)	Area ratio	Transfer function (dB)	Transfer function ratio	Adjusted lot allowance (dB)
1	21	22080	0.04	58	0.11	24
2	21	31921	0.05	53	0.13	25
3	21	5170	0.01	75	0.05	20
4	21	4189	0.01	80	0.03	18
5	21	13057	0.02	77	0.04	20
6	21	8425	0.01	76	0.04	20
7	21	30305	0.05	67	0.07	23
8	21	13609	0.02	81	0.02	18
9	21	13822	0.02	81	0.02	19
10	21	12910	0.02	72	0.05	21
11	21	31151	0.05	76	0.04	22
12	21	20231	0.03	86	0.00	17
13	21	10751	0.02	84	0.01	16
14	21	6184	0.01	83	0.01	16
15	21	37311	0.06	84	0.01	20
16	21	15567	0.03	76	0.04	20
17	21	41462	0.07	83	0.02	21
18	21	13654	0.02	82	0.02	18
19	21	20024	0.03	86	0.00	17
20	21	33379	0.05	**87**	0.00	18
21	21	206019	0.33	77	0.04	27
22	21	13146	0.02	61	0.10	23
23	21	12590	0.02	**48**	0.14	25
Total	35	616956	1		1	35

All receivers need to have the same criterion, and results are dependent on which receivers are chosen as source points when generating the contours.

The risk map is not limited by the number of receivers, and can handle the case of different criteria for different receivers.

Generating a risk map requires significant post-processing: outputs of a noise model need to be transformed into useful data structures, an optimisation algorithm is used to determine optimal sound power levels. These levels need to be converted to equivalent sound power densities, which are used to generate a raster from which contours can be generated.

There is also some subjectivity in selecting appropriate thresholds when determine areas of low, medium, and high risk.

Outputs of the risk maps can be used by both planners and developers.

Planners can assess an area of land for its suitability for industrial activity, and experiment with the effect on the risk map of changing receivers criteria (e.g. by rezoning).

Developers can use the outputs to determine what kind of industry the area in the precinct can support. There is a level of concern in how the sound power density can be interpreted by acousticians, proponents and regulators. There is also some uncertainty in the modelling and post-processing in realistically incorporating typical industrial precinct absorption and shielding characteristics.

Once a concept or master plan for a site has been developed, a conceptual noise allocation model should be used to determine equitable noise goals for individual lots in the precinct.

Noise goals are given by a maximum allowable contribution at a receiver. The allowances per lot are used in a detailed noise model to determine the appropriate mitigation measured needed for the lot. The allocations allow for the amalgamation of lots, where for example Lots 1-3 may form a super lot and their respective allocations can be logarithmically summed.

The aim of the concept allocation noise model is to consider relative location and lot area to more equitably distribute noise allocations in a precinct. The k factor can be optimised to favour area or location of the lot to help plan a precinct.

6 CONCLUSIONS

This paper describes three methods for assessing an area designated for industrial use or expansion of an existing industrial area. The reverse model generates a map showing likely areas that will be suitable for different industrial activities. It is limited by the number and type of receivers that can be considered.

A risk map is a more flexible method for determining areas of risk of noise impact in the area. It can handle multiple receivers with different criteria. The outputs of the risk map are useful for both planners - to determine the suitability of an area for industrial use - and developers - to determine what activities are suitable within the area.

The final stage before a detailed assessment can be undertaken is concept noise allowance modelling. Here, a concept or master plan is used to generate equitable noise goals for lots within the precinct. A noise goal is the maximum allowable noise contribution a lot can have at a receiver. The allowances can form part of an endorsed master plan or conditions of approval and would be tied to specific lots.

A live noise model can be created to ensure compliance with the strategic noise plan and allocated noise allowances. As new lots are developed, the model can be updated and noise goals reevaluated.

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