How to maximise the operating fleet and still comply with the noise limits

Dave J. Davis

ABSTRACT

Construction sites and mine sites often have strict noise limits during certain time periods, eg. during the night, weekends and public holidays. Site managers would often like to know what is the most activity that can occur on site simultaneously during periods of restricted noise emissions. Using engineering optimisation techniques it is possible to accurately determine the maximum number of fixed plant and mobile equipment that can be operating together at any time while still complying with the noise emission limits. This paper presents the results of determining the recommended fleet quota using Genetic Algorithms as a post-processing technique based on the noise propagation information from proprietary environmental noise modelling software.

1. INTRODUCTION

Construction sites and mine sites have several things in common. They each have multiple noise sources operating simultaneously, and they each have many different types of noise sources that are used at different times of the day, evening or night. At both mines and construction sites, many of the noise sources are stationary: some are permanently fixed, while others move from point to point and stay for periods of time eg. hours, days, weeks or months. Also, many of the noise sources are mobile: some are constantly moving eg. trucks, dozers, rollers and graders, while others move slowly eg. trenchers and excavators.

For both mines and construction sites, the production schedule will require the fixed plant and mobile equipment to operate at various times of the day and night, and while the operators will have in mind an intended average productivity for each item, in reality there will be some flexibility of when the items must operate. For instance, a construction site may have a conveyor transporting rock and soil from the cutting face to the spoil handling area, and then loaders and trucks taking the spoil away off site. If the loaders and trucks would generate excessive noise from the spoil handling area during the night, it may be possible to run the conveyor all night and simply stockpile the spoil overnight so the loaders and trucks can take it away during the day.

The production schedule requirements of both mines and construction sites change with time. Depending on the size of the project, the number of items of plant and equipment on site can change significantly.

For both cases of mining operations and also construction sites, the aggregate location of a group or cluster of noise sources can change slowly over a large periods of time. However it is more common for both construction sites and mines to have several clusters of noise sources operating simultaneously.

2. OPTIMISATION TO MAXIMISE THE OPERATING NOISE SOURCES

Optimisation can be used for several different purposes including:

- To achieve a specific outcome using the minimum amount of resources
- To achieve the best possible outcome with limited resources
- To achieve the best possible compromise or balance between use of resources and the outcomes achieved

For a mining operation or a construction site, if the noise level limits at receptors were considered to be an allowable 'noise budget' not to be exceeded, then in mathematical terms it is effectively a limited resource, and the goal of an optimisation exercise could be to determine the maximum possible noise sources that can be simultaneously active without exceeding the 'noise budget'.

There are several types of optimisation techniques that may be suitable for such an exercise. Since the decision process for the noise sources is to choose between the two possible states of 'active' or 'not active' (which is essentially 'on' or 'off') for each item of plant or equipment, the variables are discrete (in this case, binary) therefore the applicable family of optimisation techniques are the 'combinatorial' methods (Haupt & Haupt, 2004).

A readily implementable combinatorial optimisation method for this type of noise management project is the Genetic Algorithm, because it can be used for any number of noise sources, with any number of noise receptors, and each receptor can have a different set of noise limits for different time periods.

When using the Genetic Algorithm for the example discussed, the variables are the noise sources that can be either ‘on’ or ‘off’, the constraints are the noise limits at the receptors, and the objective function to be minimised could be eg. the sum of squares of the excess compliance at the receptors.

3. MULTIPLE SIMULTANEOUS LOCATIONS OF CLUSTERS OF NOISE SOURCES

Some construction projects involve multiple construction workfronts occurring simultaneously. An example construction schedule for a large project with multiple simultaneous workfronts with a 20 month construction program is shown in Table 1. The locations of the workfronts and the noise receptors are shown in Figure 1.

For the construction workfronts shown in Table 1 and Figure 1, a different fleet of equipment was to be used in each of the worksite areas during standard construction hours. Many of the noise sources involved in the construction project move around the site at various speeds and rates of progression. Some such as trucks move generally from one point to another along a relatively unchanging path, and these should be modelled as line noise sources. Others such as dozers and graders may move across the entire site in a sweeping pattern and these may need to be modelled as area noise sources, with the assumption that the noise source would traverse the entire area within the time period of the noise measurement at the receptor(s). Alternatively if a more conservative representation was desired, the plant and equipment could be modelled as point noise sources in locations that represented the worst-case noise immission at receptors. Some noise modelling software such as SoundPLAN has the ability to model the L_{Amax} from a line or an area source as though it was generated from any point along or across the source and for the purposes of this type of investigation that particular assumption may sometimes be the best approach.

Table 1. Construction schedule of a project with multiple simultaneous workfronts

Areas	Sub-Areas	Type of works	Dates		Duration (months)
			Start	Finish	
Worksite 1	W1 - Area A	Earthworks	30/09/2015	5/10/2016	12
		Pavement	30/09/2015	5/10/2016	12
	W1 - Area B	Earthworks	30/04/2015	15/08/2016	16
		Pavement	30/04/2015	15/08/2016	16
		Building/Infrastructure	30/04/2015	15/08/2016	16
Worksite 2	W2 - Area A	Earthworks	31/10/2014	24/06/2016	20
		Pavement	31/10/2014	24/06/2016	20
	W2 - Area B	Earthworks	31/12/2014	24/06/2016	18
		Pavement	31/12/2014	24/06/2016	18
	W2 - Area C	Earthworks	30/04/2015	15/08/2016	16
		Pavement	30/04/2015	15/08/2016	16
		Haulage	31/10/2014	31/07/2015	9
Worksite 3	W3 - Area A	Mobilisation	1/10/2014	31/10/2014	1
		Earthworks	31/10/2014	26/04/2016	18
		Pavement	31/10/2014	26/04/2016	18
		Haulage	31/10/2014	31/07/2015	9
	W3 - Area B	Earthworks	30/09/2015	23/06/2017	21
		Pavement	30/09/2015	23/06/2017	21
	W3 - Area C	Earthworks	30/06/2016	23/06/2017	12
		Pavement	30/06/2016	23/06/2017	12

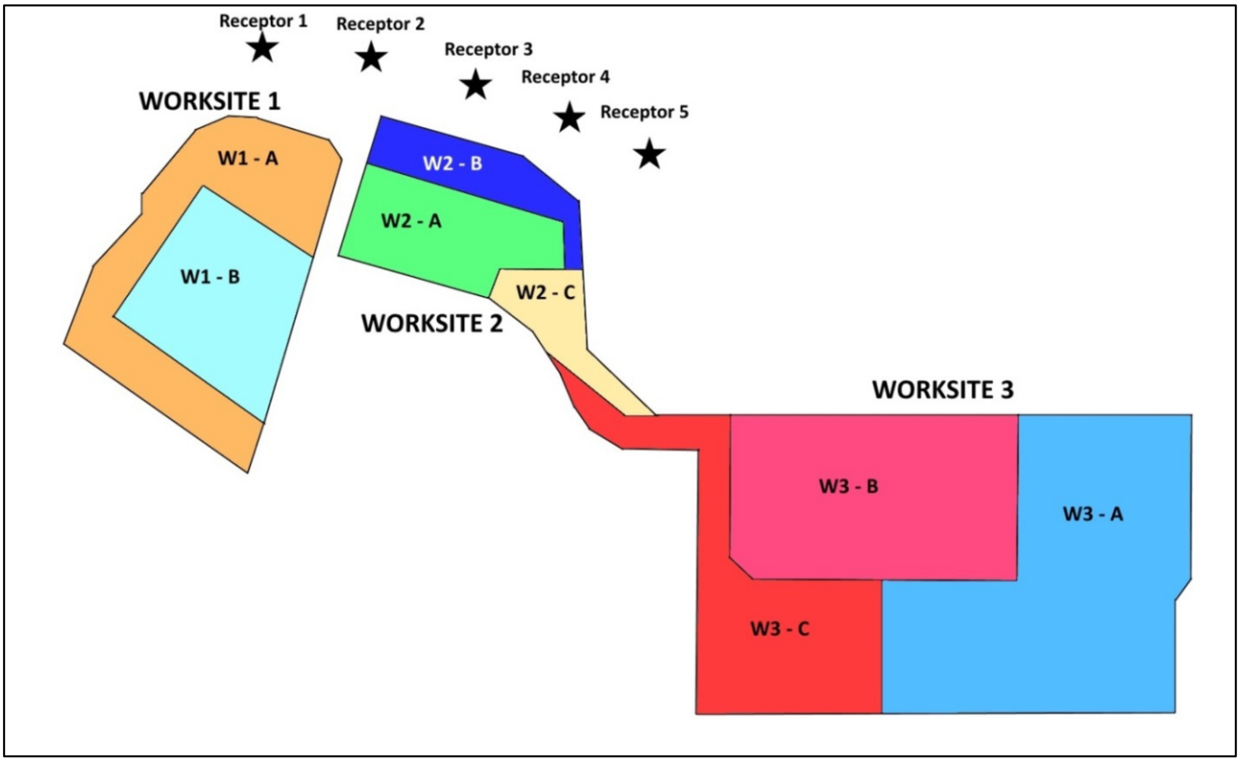

Figure 1. Construction workfront areas

4. NOISE LEVEL LIMITS

Noise sources such as mines and construction sites typically have different noise limits for day, evening and night time periods, and possibly also have special case noise limits for certain days of the week and/or public holidays.

In the example shown in Section 3, there were several different noise receptors in close proximity to the site. There were no quantitative noise limits during weekdays, and noise during the night was not permitted.

The noise level limit applicable at all receptors for construction activities outside of normal construction hours (ie. during weekday evenings and weekend daytime hours) was 58 dB(A) Leq(30min).

5. DESIRED OUT-OF-HOURS CONSTRUCTION FLEET

The project desired to know what would be the maximum number of plant items that could operate out-of-hours at each of three worksites, and also what plant could operate if out-of-hours work was required at all three sites simultaneously.

Optimisation of the construction fleet was undertaken to ensure that the noise limits were met at all receptors for the following situations:

1. Out-of-hours earthworks at Worksite 1
2. Out-of-hours earthworks at Worksite 2
3. Out-of-hours earthworks at Worksite 3
4. Out-of-hours earthworks at Worksites 1, 2 and 3 simultaneously

The noise modelling approach was to assume a ‘standard’ out-of-hours construction fleet, to calculate the expected noise levels at receptors and to use that model as the starting point for the optimisation.

Noise levels from the standard complement of equipment were found to exceed the noise limits at one or more receptors while works occurred for Situations 1, 2 and 4 above. The starting complement of the ‘standard’ out-of-hours earthworks equipment is shown in Table 2. The resulting noise levels at receptors are shown in

Table 3. As shown in Table 3, the noise limit of 58 dB(A) was exceeded at one or more receptors in all cases except during out-of-hours works at Worksite 3.

Table 2. 'Standard' out-of-hours earthworks equipment

Plant	× Number of
Grader	1
Water Cart	1
Rollers	2
Light Vehicles	2
Truck & Dog	4

Table 3. Noise from 'standard' out-of-hours earthworks equipment

Worksite(s)	Noise level at receptor dB(A)				
	Receptor 1	Receptor 2	Receptor 3	Receptor 4	Receptor 5
1	49.9	55.5	59.0	54.2	58.4
2	51.9	56.7	60	53.3	56.9
3	49.2	49.8	50.7	51.8	52.8
1+2+3	55.3	59.6	62.8	58.0	61.4

6. OPTIMISATION OF OUT-OF-HOURS CONSTRUCTION FLEET TO COMPLY WITH NOISE LIMITS

The noise sources were modelled separately as either point, line or area sources as appropriate, as described in section 3. The component contribution noise levels from each noise source at each receptor were then assembled in a table, which was used as the list of input variables for the genetic algorithm software. The algorithm then calculated the total noise level at each receptor for various combinations of the separate noise sources being turned "on" or "off". The optimisation algorithm searched within the solution space to maximise the fleet with the constraint that the resulting noise levels were forced to comply with the noise limits at all receptors for weekend/evening works, for all modelling scenarios.

The optimised fleets of equipment that were forced to comply with the weekend/evening noise guideline limits are shown below.

6.1 Out-of-hours noise sources at Worksite 1

The out-of-hours noise sources at Worksite 1 that were optimised to comply with the weekend/evening guideline noise limits are shown in Table 4. The resulting noise levels at receptors with the optimised fleet are shown in Table 5. As shown in Table 5, the noise limit of 58 dB(A) is met at all receptors with the optimised construction fleet.

Table 4. Optimised out-of-hours noise sources at Worksite 1

Plant	× Number of
Grader	1
Water Cart	1
Rollers	1
Light Vehicles	2
Truck & Dog	3

Table 5. Noise from optimised out-of-hours construction at Worksite 1

Worksite	Noise level at receptor dB(A)				
	Receptor 1	Receptor 2	Receptor 3	Receptor 4	Receptor 5
1	48.9	54.4	57.9	53.0	57.4

6.2 Out-of-hours noise sources at Worksite 2

The out-of-hours noise sources at Worksite 2 that were optimised to comply with the weekend/evening guideline noise limits are shown in Table 6. The resulting noise levels at receptors with the optimised fleet are shown in Table 7. As shown in Table 7, the noise limit of 58 dB(A) is met at all receptors with the optimised construction fleet.

Table 6. Optimised out-of-hours noise sources at Worksite 2

Plant	× Number of
Grader	1
Water Cart	1
Rollers	1
Light Vehicles	2
Truck & Dog	1

Table 7. Noise from optimised out-of-hours construction at Worksite 2

Worksite	Noise level at receptor dB(A)				
	Receptor 1	Receptor 2	Receptor 3	Receptor 4	Receptor 5
2	49.2	53.8	57.5	50.7	54.2

6.3 Out-of-hours noise sources at Worksite 3

The out-of-hours noise sources at Worksite 3 that were optimised to comply with the weekend/evening guideline noise limits are shown in Table 8. The resulting noise levels at receptors with the optimised fleet are shown in Table 9. As shown in Table 9, the noise limit of 58 dB(A) is met at all receptors with the optimised construction fleet.

Table 8. Optimised out-of-hours noise sources at Worksite 3

Plant	× Number of
Grader	1
Water Cart	1
Rollers	2
Light Vehicles	2
Truck & Dog	4

Table 9. Noise from optimised out-of-hours construction at Worksite 3

Worksite	Noise level at receptor dB(A)				
	Receptor 1	Receptor 2	Receptor 3	Receptor 4	Receptor 5
3	49.2	49.8	50.7	51.8	52.8

6.4 Out-of-hours noise sources at Worksites 1, 2 and 3 simultaneously

The out-of-hours noise sources in all three worksites that were optimised to comply with the weekend/evening guideline noise limits are shown in Table 10. The resulting noise levels at receptors with the optimised fleet are shown in Table 11 As shown in Table 11, the noise limit of 58 dB(A) is met at all receptors with the optimised construction fleet.

Table 10. Optimised out-of-hours noise sources at Worksites 1, 2 and 3

Plant	× Number of		
	Worksite 1	Worksite 2	Worksite 3
Grader	0	0	0
Water Cart	1	1	1
Rollers	1	1	1
Light Vehicles	2	2	2
Truck & Dog	1	1	3

Table 11. Noise from optimised out-of-hours construction at Worksites 1, 2 and 3

Worksites	Noise level at receptor dB(A)				
	Receptor 1	Receptor 2	Receptor 3	Receptor 4	Receptor 5
1 + 2 + 3	51.4	55.4	58.0	54.2	57.2

7. SUMMARY

The Genetic Algorithm is ideal for maximising the fleet at an operating mine or a construction site, because it can be used for any number of noise sources, with any number of noise receptors, and each receptor can have a different set of noise limits for different time periods. The technique can be used in situations where the locations of noise sources change slowly over long-term projects, or where there are multiple simultaneous locations of clusters of noise sources during short-term to medium-term projects.

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