A Case Study on Noise Mapping for Container Terminals at the Port of Los Angeles

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ABSTRACT

The Los Angeles-Long Beach Port complex is the nation's largest ocean freight hub and its busiest container port complex, where the goods going through the Port grow increasingly, especially in the container division. As the container sector has the highest growth potential, the levels of noise generated by the ships, straddle carriers, cranes, fork lifts, refrigerated containers, trucks and trains may present a problem. The purpose of this study is to model the noise levels (i.e. noise mapping) generated from container terminals at the Port of Los Angeles. The noise map provides a geographical view of the noise distribution in and around the Port areas and can help the port authorities assess the current noise pollutions as well as to investigate the potential noise impact of future development plans of the Port. This paper presents the development of noise maps for container terminals at the Port of Los Angeles, which may be used to predict future noise levels of the surroundings. A mathematical model and a computer noise modeling software used to generate the noise maps will be discussed. The noise maps are then used to identify any critical areas within the Port where noise levels exceed the noise standard levels stipulated in the Los Angeles County Noise Control Ordinance and the World Health Organization community noise guidelines.

Keywords: Noise Mapping, Transportation Noise, Container Terminals, Seaport

1. INTRODUCTION

The Port of Los Angeles was officially established in 1907 by a State Tidelands Grant to the City of Los Angeles and encompasses 7,500 acres of land and water and 43 miles of waterfront. Nowadays, the Port has become the number one port by container volume and cargo value in the United States. The Port of Los Angeles has held this distinction consistently since 2000. In 2006, the Port moved an impressive 8.5 million twenty-foot equivalent unit (TEU) containers that established a new national container record. For the second consecutive year, the Port of Los Angeles experienced record-breaking exports as outbound container volumes surged in 2011 (7.9 TEUs) and 2010 (7.8 TEUs). The Port currently houses 26 cargo terminals (see Figure 1), which handle import/export liquid bulk, dry bulk, break bulk, cruise passengers and containerized cargo. Among these terminals, the container terminals were selected as the target of this study due to the fact that 90% of all cargo handling equipment operated at the Port is used at container terminals. As the container sector at the Port has the highest growth potential, the levels of noise generated by the ships, straddle carriers, cranes, forklifts, trucks and trains may present a problem and have become a major concern to environmental and governmental agencies in recent years. So there is a need for an appropriate noise study to ensure that the noise levels in the port and the surrounding areas do not exceed a reasonable level. The purpose of this study is to model the noise levels (i.e. noise mapping) generated from container terminals at the Port of Los Angeles. The noise map provides a geographical view of the noise distribution in and around the Port areas and can help the port authorities assess the current noise pollutions as well as to investigate the potential noise impact of future development plans of the Port. As part of the study, field noise and activity data were collected at different locations around the Port near the container terminals in order to validate the noise model. The data were compiled into noise charts which provide detail insights into the noise and activity variations by hour, day of the week, and month at the different locations. Also, the noise charts can be used to identify the peaks of noise levels and dominant noise sources. The remaining of the paper is organized as follows: (i) Terminals at the Port of Los Angeles; (ii) Developing noise maps; (iii) Results and discussions; and (iv) Conclusions.

2. TERMINALS AT THE PORT OF LOS ANGELES

The terminals at the Port of Los Angeles (see Fig 1) can be classified into the following categories: container, break-bulk, dry bulk, liquid bulk, auto, and cruise passenger/ferry. The Port of Los Angeles has nine major container terminals and four dockside intermodal rail yards with direct access to the Alameda Corridor, a 20-mile express railway connecting the

Port to the rail hubs in downtown Los Angeles. Below is the list of container terminals at the Port of Los Angeles which were selected for this noise study:

- Berth 100: WEST BASIN CONTAINER TERMINAL
- Berths 121-131: WEST BASIN CONTAINER TERMINAL
- Berths 135-139: TRANS PACIFIC CONTAINER SERVICE CORP. (TraPac)
- Berths 206-209: PORT OF LOS ANGELES CONTAINER TERMINAL
- Berths 212-225: YUSEN CONTAINER TERMINAL
- Berths 226-236: EVERGREEN CONTAINER TERMINAL
- Berths 302-305: APL TERMINAL/GLOBAL GATEWAY SOUTH
- Berths 401-404: APM TERMINALS/PIER 400
- Berths 405-406: CALIFORNIA UNITED TERMINALS

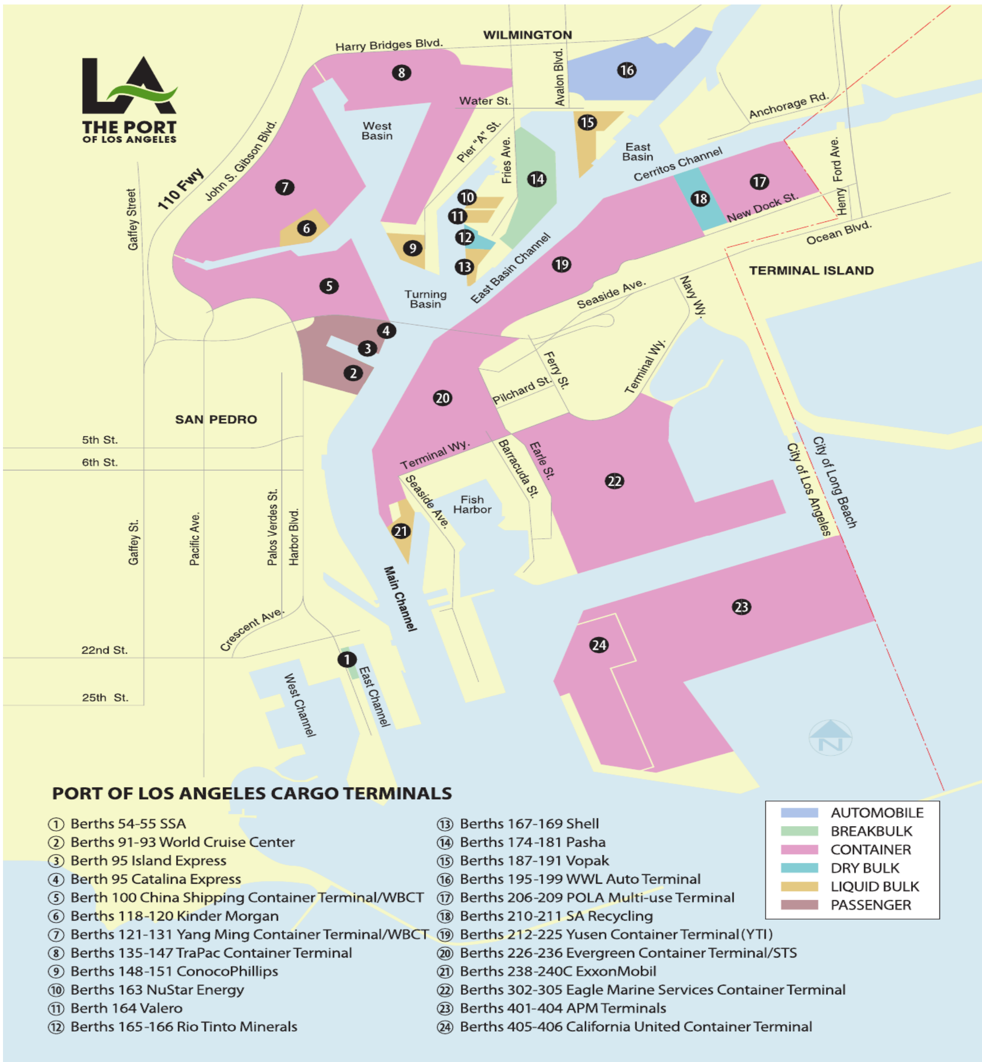

Figure 1 Port of Los Angeles Terminals

A survey on container terminals at the Port was conducted to determine representative locations in the terminals for collecting actual noise data. These locations are mainly entrance/exit gates of the terminals and are assigned as follows: Location # 1 includes Berths 401-406; Location # 3 includes Berths 302-305; Location # 4 includes Berths 226-236; Location # 5 includes Berths 212-225; Locations # 6 & 7 include Berths 135-139; Location # 8 includes Berth 100; and Location # 9 includes Berths 121-131. Noise levels generated during the container terminal operations vary depending on the type of equipment and the nature of the work being performed. Operation of the container terminals at the Port of Los Angeles involves the following main sources of general plant noise: gantry container cranes, ship generators, road trucks, trains, forklifts, yard tractors, RTG cranes. The contribution from all these sources of noise was included in this study using noise mapping.

3. DEVELOPING NOISE MAPS

The development of noise maps (i.e. noise mapping) for the container terminals at the Port of Los Angeles is the main purpose of this study. The noise map represents a geographical view of the noise distribution in and around the Port areas, which can be used to identify if there is any potential noise impact on the future development plans of the Port. The development of noise maps for the container terminals at the Port can be done by means of a noise modelling software, named SoundPLAN, in which mathematical models are used to predict noise levels. The following sub-sections will present the mathematical model and the development of a noise map using the software SoundPLAN.

3.1 Mathematical model for predicting noise levels

The mathematical model for A-weighted equivalent noise level produced by the cargo handling equipment/trucks used at the port terminals is derived in accordance to the models described in [12]. The derivation is based on the following statistical hypotheses in accordance with those previously assumed by [21]. The distribution of the noise sources, i.e. cargo handling equipment/trucks, is describable using a Poisson distribution. In other words, the noise sources are distributed as a traffic flow on the path with the same average density ρ and the probability that an event happens in a short interval of time t is $p = \rho \times t$. The sound emission is non-directional (monopole). Considering a one lane path AB (Refer to Figure 2) and a flow of the noise sources less than 500 vehicles/hr, the description of the traffic flow as a Poisson distribution is valid [18]. The probability that x vehicles arrive at the measurement point during a given time τ is:

$$P_x = \left[\frac{\mu^x}{x!}\right] e^{-\mu} \tag{1}$$

where: x : number of vehicles in τ , $\mu = \lambda\tau$, $\lambda = N/T$

N : number of vehicles in measurement time T

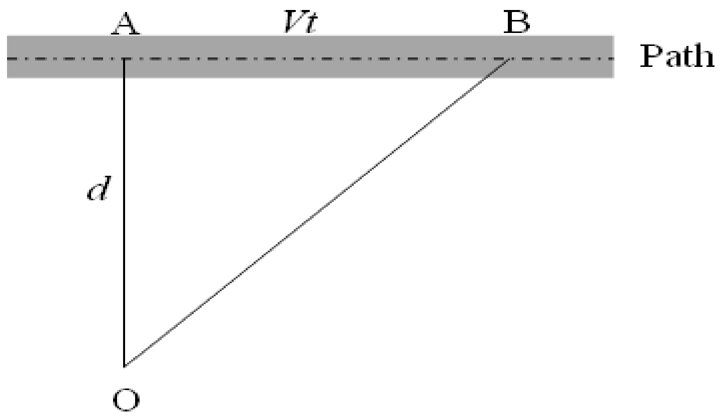

Figure 2 The Geometry for a Single Noise Source in a Single Lane

Given a single point noise source moving from A to B along the straight path (as shown in Figure 2) at an average speed V (km/hr) in the time t and let d be the perpendicular distance from the observer at point O to the path, it is possible to write for the A-weighted sound pressure level (L_p) produced by the unit vehicle at the observer point O [15], assuming the ground is a perfectly reflecting surface and ignoring the sound attenuation caused by air absorption.

$$L_P = L_W - 8 + 10log\left[\frac{1}{d^2 + (Vt)^2}\right] \tag{2}$$

where L_W: A-weighted sound power level of the noise source (dB)

The A-weighted equivalent noise level (L_{eq}) produced by the unit in the time interval $[t_1, t_2] = t$ at point o (the observer) is

$$L_{eq} = 10\log\left(\frac{1}{t}\int_{t1}^{t2} 10^{\frac{Lp}{10}}\, dt\right) = L_w - 8 - 10\log(Vd) + 10log\left(\frac{2tan^{-1}\left(\frac{Vt}{2d}\right)}{t}\right) \tag{3}$$

Let L_o be the background noise level and considering the time interval t in which the A-weighted sound pressure level (L_P) of the noise source at the observer point O is 10 dB higher than L_o, we can write:

$$L_P - L_o \geq 10 \tag{4}$$

Lp in Eq. (4) can be substituted by Eq. (2) and we get for t as follows:

$$t = \left(\frac{2d}{V}\right)K \tag{5}$$

Where:

$$K = \sqrt{10^{\frac{(Lw - 20\log(d) - Lo - 18)}{10}} - 1} \tag{6}$$

Finally, the A-weighted equivalent noise level at the observer point O from Eq. (3) can be expressed as:

$$L_{eq1} = L_w - 8 - 20\log(d) + 10log\left(\frac{tan^{-1}(K)}{K}\right) \tag{7}$$

It is also noted that Eq. (7) is valid only within the limits of distance d below.

$$d < 10^{\left(\frac{Lw - Lo - 18}{20}\right)} \tag{8}$$

3.2 Development of a noise map using the software SoundPLAN

In this particular study, the noise map (or noise model) for the container terminals at the Port of Los Angeles was developed using a commercial noise modeling software, i.e. SoundPLAN from Braunstein & Berndt. Basically, the noise map is generated as follows:

- First, a digital 3D spatial and elevation model of the container terminals area is created in the SoundPLAN software.
- Next, all the noise sources (e.g. road, rail, industrial equipment etc.) at the port are located in the model. These noise sources could be a point (e.g. a crane), a line (e.g. a railway track), or an area (e.g. a berth). An area source, i.e. a number of point sources, is used to determine noise levels for a region when the noise levels of its point sources are mixed and cannot be separated from each other.
- The next step is to designate receivers and grids on the model, which define the points where the calculation of the noise levels will take place. The receivers could be placed at specific points of noise interest such as limits of the port area or at the boundary of residential areas. The grids comprising a network of receivers are horizontal or vertical surfaces which are defined by different color codes. The distance between the grid's receivers (density) could vary according to the application. After the grids and receivers are located in the model, the calculation parameters (e.g. technical information and meteorological data) are set. The meteorological data to be input include the annual averages of temperature, relative humidity, atmospheric pressure, wind direction and speed; which can be obtained from the port authority, municipality or regional environmental agency, or measured in the field.
- Finally, the noise levels or acoustical characteristics of each source are entered into the computer software to obtain the noise model for the area under study.

4. RESULTS AND DISCUSSIONS

This section highlights several selected results from this noise study, which specifically include: Noise distributions; Noise maps for the Port; and Evaluation of noise impact using noise maps.

4.1 Noise distributions

The noise data collected from the port can be viewed in different distributions (e.g. hourly, daily, and monthly distributions) in order to identify the noise peaks. For instance, the average hourly noise distribution reveals that the noise peaks around 9am (72.9dB), tapers off after that to a minimum of 71.9dB around 1pm, and peaks again around 2pm and 3pm (72.5dB). This hourly noise distribution is found to be consistent with the operating characteristics of the container terminals at the port. According to the average daily noise distribution, the average noise level has a slight peak on Friday (72.7 dB) and the lowest noise level is on Wednesday (71.6 dB). The average monthly noise distribution indicates that the noise peaks in July through September (73.6-73.9 dB) and the lowest noise level is in December (70.7dB).

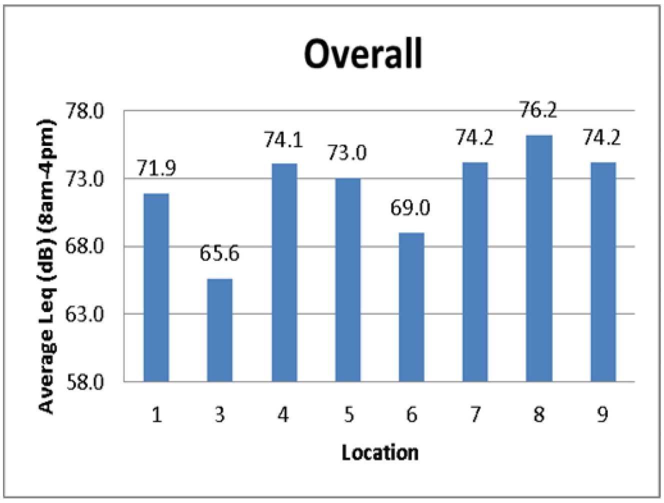

Figure 3 Overall average noise level for each location

In addition, the overall noise distribution by locations (Figure 3) obtained from this study shows that Location 8 has the highest noise (76.2dB), followed by Location 7 & 9 (74.2dB) and then Location 4 (74.1dB). Locations 3 and 6 have the lowest noise, 65.6dB and 69 dB respectively.

4.2 Noise maps for the Port

Figure 4 shows a typical noise map for the Port created from the software SoundPLAN for the day period (6am-10pm). For the validation purpose, the noise levels for each location obtained from the SoundPLAN noise map by means of mathematical models were then compared with the average noise levels measured from the field; which are presented in Table 1.

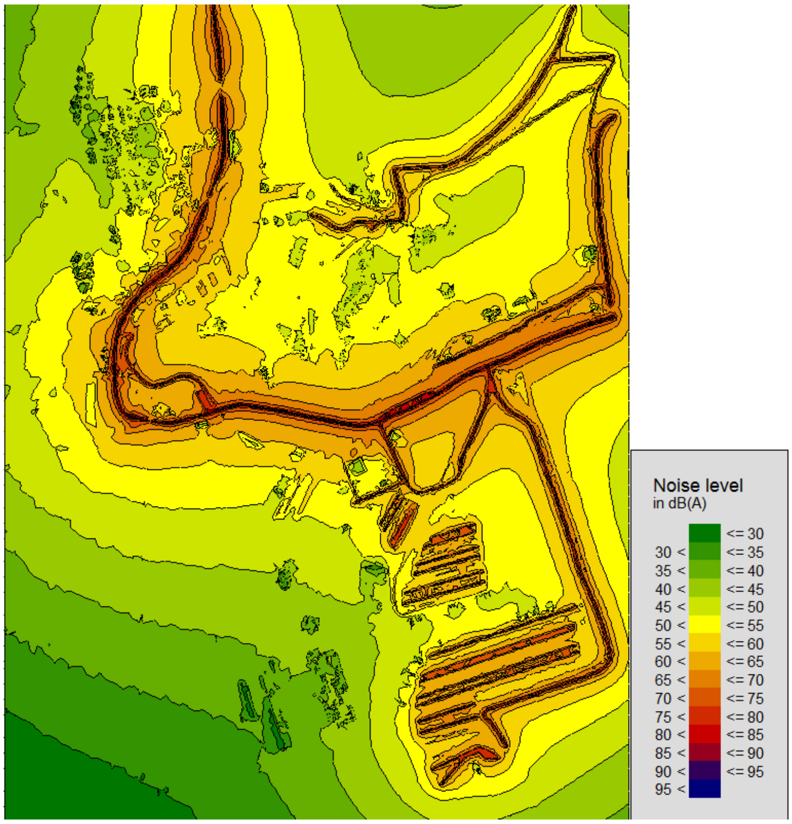

Figure 4 Overall noise map for day period (6am-10pm)

It can be seen that the differences are within the acceptable range for all locations except Location 3. For location 3, the actual site elevation is higher than the elevation in the noise model due to recent construction that is not included in the digital elevation model. So the higher spot acts as a noise barrier resulting in lower observed noise than the simulation. In general, the measured noise data corroborates well with the noise levels given from the created noise map. It can be concluded that the accuracy of the noise map is validated.

Table 1: Comparison of noise levels given from the noise map with average noise levels measured from the field

Location	Noise Levels given from the Noise Map (dB)	Average Noise Measured from the Field (dB)	Difference (dB)
1	70.3	71.9	-1.6
3	68.3	65.6	2.7
4	72.7	74.1	-1.4
5	74.2	73.0	1.2
7	72.4	74.2	-1.8
8	75.4	76.2	-0.8
9	74.4	74.2	0.2

4.3 Uses of noise maps

The noise maps can be used to evaluate the noise impact on the residential area to the west of the port. The results from this study indicate that the noise levels around the residential neighborhood of the port do not exceed 55dB during the day period; which is within the Community Noise Exposure guidelines of the LA municipal code. The noise drops steadily further west of the port. During the night period, the noise levels in the area are less than 50dB. In order to further analyze and identify the most dominant noise source, the noise maps are generated for each type of noise source acting alone, e.g. truck activities only (Figure 5), cargo handling activities only (Figure 6), and train activities only (Figure 7). From these noise maps, it is obvious that the truck movement activity is the highest source of noise, while train activity contributes the least to the overall noise.

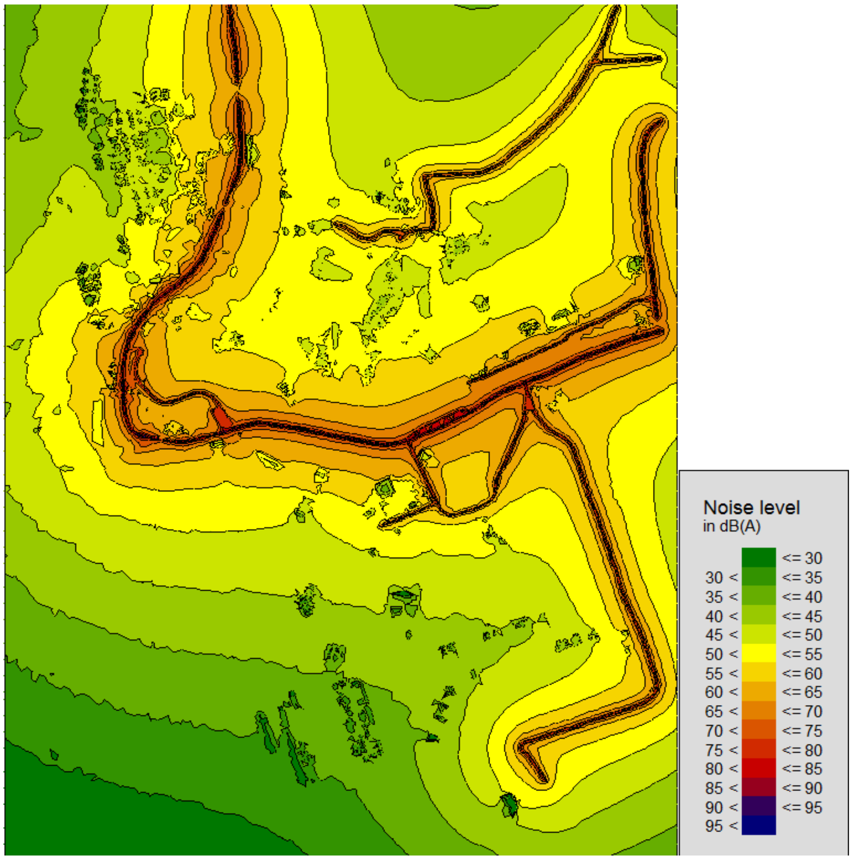

Figure 5 Noise map for day period (6am-10pm) with only truck traffic

Looking at the noise map for the truck activities only, it can be seen that the noise is concentrated on the roads and radiates outwards. Using the Caltrans/FHWA Noise Abatement Criteria for Category C activities, it can be observed that the noise level is within the 71dB limit for developed land 50 feet away from the major roads (not counting the Freeway). The noise from the cargo handling activities is next checked using the LA municipal code for industrial equipment noise, which stipulates a limit of 75dB 50 feet away. Using the noise map for the cargo handling activities, it is easy to see that the noise is well within the limit.

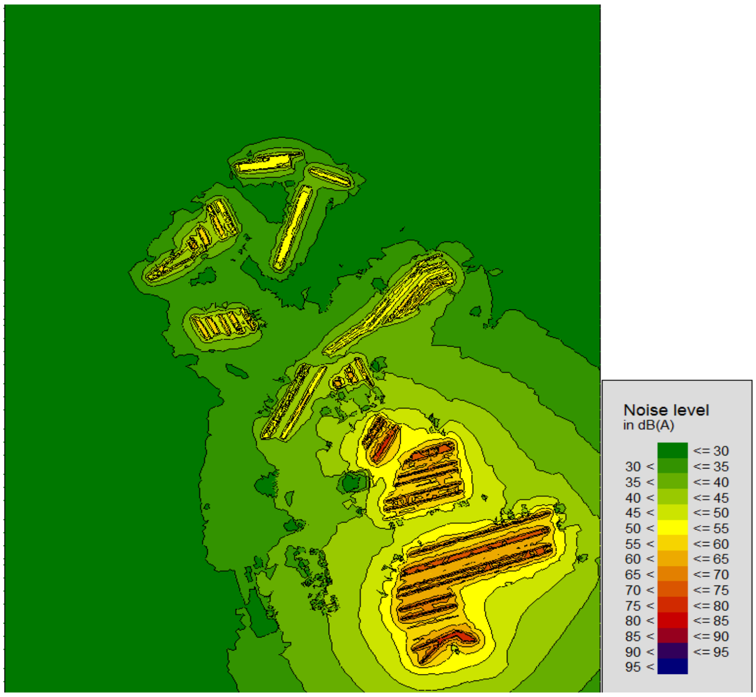

Figure 6 Noise map for day period (6am-10pm) with only cargo handling activities

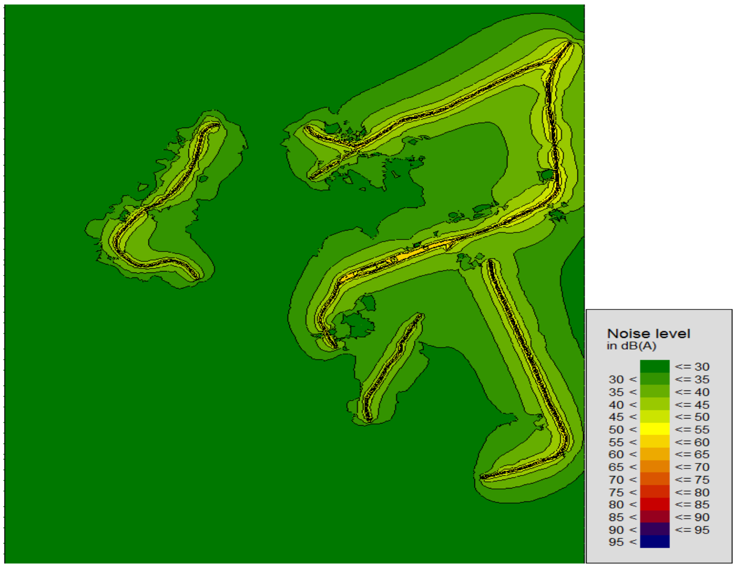

Figure 7 Noise map with only train activities

The key findings from this noise study are summarized in Table 2 below.

Table 2: Summary of the key findings

Findings	**Highest**	**Lowest**
Hourly noise	76.9dB (Location 8 around 9am)	65dB (Location 3 around 1pm)
Daily noise	72.7dB (Friday)	71.6dB (Wednesday)
Monthly noise	78.4dB (Location 4 in September)	63.7dB (Location 3 in December)
Overall noise	76.2dB (Location 8)	65.6dB (Location 3)
Overall truck activities	538 trucks/hr (Location 1)	267 trucks/hr (Location 5)

5. CONCLUSIONS

The noise maps generated from this study illustrate the relative contribution of different groups of noise sources (e.g. road traffic, rail traffic and industrial noise). The noise sources in the port areas can be broadly grouped into two major categories: industrial activities and traffic related activities. The industrial noise sources include cargo handling, container handling, cranes, vehicles, auxiliary equipment, etc.; whereas the traffic related noise sources are roads, vehicles, railways, trains, etc. The results from this study reveal that trucks are the primary contributor of container activities noise in the Port, followed by cargo handling equipment. In general, the noise levels generated from the port, however, are all within the allowable noise limits. It is found that the charts of noise distributions by different groups of noise sources are useful as they can assist the Port authority in identifying hot spots and high priority areas. Academically, these noise distribution charts can help understand noise problems at ports and can be used as teaching tools in classes of noise pollution and/or sustainable environment. Further, those charts of noise distributions can be used to evaluate the impact of different noise sources on the high priority areas, thus helping professionals of the Port authority and policy makers of the California State in developing appropriate noise action plans and noise regulations, respectively. In order to reduce or eliminate the impact of noise pollution in the port and its surroundings, appropriate action plans for noise management as well as noise reduction measures should be developed and implemented at an early stage.

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