NOISE MAPPING OF CONTAINER TERMINALS AT THE PORT OF LOS ANGELES

FINAL REPORT

METRANS PROJECT 11-26

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Abstract

Noise emissions from various transportation modes including seaports have become a major concern to environmental and governmental agencies in recent years for the great annoyance they cause to surrounding communities. 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 grows 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. In addition, noise emitted from container terminals, at high levels and for long periods, has a negative impact on the performance of the different parties involved in the cargo handling activities at the container terminals as well as the life of the residential neighbors. The purpose of this study is to predict and model the noise of container terminals at the port of Los Angeles. Specifically, the objectives of the study are as follows:

1. Develop a noise model (noise mapping) for the port of Los Angeles, which may be used to predict future noise levels of the surroundings.
2. Determine the dominant noise sources within container terminals at the port.
3. Measure the noise levels around the container terminals. These on-field noise measurements will be used for validation of the developed noise model and assessment of noise mitigation.
4. Identify the areas within the port where noise levels exceed the noise standard levels stipulated in the Los Angeles County Noise Control Ordinance and the WHO (World Health Organization) community noise guidelines.
5. Provide any noise mitigation requirements for the port to meet the L.A. City and WHO required noise limits.

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1.0 Introduction

This section provides a background on noise mapping for the container terminals at the Port of Los Angeles. Specifically, it will discuss an overview of noise standards and noise maps for the Port of Los Angeles.

1.1 Overview of noise standards

This sub-section discusses standard noise levels, noise regulations, human responses to noise and impacts of noise.

1.1.1 Standard noise levels

Noise regulations have been developed by several organizations to provide guidelines on how to determine standard noise levels. As acoustic terms to be used throughout this report may not be familiar to the reader, it would be helpful to provide definitions of these terms before further discussions.

Decibels (dB): A unit describing the amplitude of sound, equal to 20 times the logarithm to the base 10 of the ratio of the pressure (intensity) of the sound measured to the reference pressure. The reference pressure for air is 20 micro Pascals

Sound pressure levels: Sound pressure is the sound force per unit area, usually expressed in micro Pascals (or micro Newtons per square meter), where 1 Pascal is the pressure resulting from a force of 1 Newton exerted over an area of 1 square meter. The sound pressure level is expressed in decibels as 20 times the logarithm to the base 10 of the ratio between the pressures exerted by the sound to a reference sound pressure (e.g., 20 micro Pascals in air). Sound pressure level is the quantity that is directly measured by a sound level meter

Frequency (Hz): The number of complete pressure fluctuations per second above and below atmospheric pressure. Normal human hearing is between 20 hertz (Hz) and 20,000 Hz. Infrasonic sounds are below 20 Hz, and ultrasonic sounds are above 20,000 Hz.

A-Weighted Sound Level (dBA): The sound pressure level in decibels as measured on a sound level meter using the A-weighting filter network. The A-weighting filter de-emphasizes the very low and very high frequency components of the sound in a manner similar to the frequency response of the human ear and correlates well with subjective reactions to noise.

Equivalent Noise Level (L_{eq}): The average A-weighted noise level during the measurement period. The hourly L_{eq} used for this report is denoted as dBA L_{eq}(h).

Ambient Noise Level: The composite of noise from all sources near and far. The normal or existing level of environmental noise at a given location.

1.1.2 Noise regulations

Several organizations have developed their own noise regulations such as WHO's Noise Guidelines and City of Los Angeles Municipal Code as presented below.

WHO's Noise Guidelines: In 1999, the World Health Organization (WHO) issued suggested community noise guidelines. It considered various environments, noise levels, and noise impacts. In outdoor living areas (backyards, for example), a noise level of 50-55 dBA averaged over the daytime is considered moderately to seriously annoying; levels above 45 dBA averaged over nighttime hours can disturb sleep; and indoor noise levels above 35 dBA impact communication in a school classroom.

***City of Los Angeles Municipal Code*:** The City of Los Angeles Municipal Code sets forth noise regulations as shown in Section 41.40 of the Code. Regarding construction noise, Section 112.05 of the Code establishes maximum noise levels for powered equipment or powered hand tools. This section discussed noise limits at a distance of 50 feet there from (a) 75 dBA for construction, industrial and agricultural machinery including crawler tractors, dozers, rotary drills and augers, loaders, power shovels, cranes, derricks, motor graders, paving machines, off-highway trucks, ditchers, trenchers, compactors, scrapers, wagons, pavement breakers, depressors, and pneumatic or other powered equipment;(b) 75 dBA for powered equipment of 20 horsepower or less intended for infrequent use in residential areas including chain saws, log chippers, and powered hand tools; and (c) 65 dBA for powered equipment intended for repetitive use in residential areas including lawn mowers, backpack mowers, small lawn and garden tools, and riding tractors. Table 1 presents the land use noise compatibility guidelines.

Table 1. Land Use Noise Compatibility Guidelines

	Community Noise Exposure CNEL, dB			
Land Use	Normally Acceptable	Conditionally Acceptable	Normally Unacceptable	Clearly Unacceptable
Single-Family, Duplex, Mobile Homes	50-60	55-70	70-75	above 70
Multifamily Homes	60-65	60-70	70-75	above 70
Schools, Libraries, Churches, Hospitals, Nursing Homes	50-70	60-70	70-80	above 80
Playgrounds, Neighborhoods Parks	50-70	—	67-75	above 72

Normally Acceptable: Specified land use is satisfactory, based on the assumption that any buildings involved are of normal conventional construction without any special noise insulation requirements.

Conditionally Acceptable: New construction or development should be undertaken only after a detailed analysis of the noise reduction requirements is made and needed noise insulation features included in the design. Conventional construction, but with closed windows and fresh air supply systems or air conditioning, will normally suffice.

Normally Unacceptable: New construction or development generally should be discouraged. If new construction or development does proceed, a detailed analysis of the noise reduction requirements must be made and needed noise insulation features included in the design.

Clearly Unacceptable: New construction or development generally should not be undertaken.

Source: City of Los Angeles, 1998

1.1.3 Human response to noise and impacts of noise

The human ear does not judge sound in absolute terms, but instead senses the intensity of how many times greater one sound is to another. Most sounds that humans are capable of hearing have a decibel (dB) range of 0 to 140. A whisper is about 30 dB, conversational speech 60 dB, and 130 dB is the threshold of physical pain. Changes of 3 dBA in the normal environment are widely accepted and are considered barely noticeable to most people. A change of 5 dBA is readily perceptible, and an increase of 10 dBA is perceived as being twice as loud.

Noise with high intensity may affect different aspects of life including causing damage to health, interrupting activities, and disrupting normal cognitive process. Different impacts of noise are summarized as follows.

- Hearing loss may be resulted from prolonged exposure to noise in excess of 85dBA.
- The stress due to noise can also lead to respiratory diseases, as well as depression and migraine.
- Increasing noise levels may cause an increase in cardiovascular risk
- It is found that a causal chain between strong noise annoyance and increased morbidity.
- A further effect of noise is sleep disturbances. Frequent or long awakenings impede the necessary recovery and rejuvenating effects of sleep, leading to decreased performance capacity, drowsiness and tiredness during the day. This in the long run can have a detrimental effect on health.

Noise impacts at the workplace:

- High-intensity industrial noise levels may result in hearing loss.
- Noise can interfere with communication and the hearing of warning signals.
- Noise causes a greater frequency of errors in performing everyday tasks and can lead to more workplace accidents. A study has found that the number of accidents per worker was highest for young workers in noisy jobs and for those who had the least experience at such jobs.
- Noise can also affect the productivity of workers. The effects of noise on performance efficiency depend on the type of noise and the nature of the task being performed. For intermittent noise, studies have shown that it impairs the speed of processing new information and the elucidation of a response. The effect however is only confined to a short period after the onset of the noise. For loud continuous noise, the effect is most detrimental for tasks involving monitoring and the use of caution. For moderate intensity noise, the effect is less serious but it can reinforce the use of a dominant response to stimuli and make the worker less flexible and adaptive to change.

1.2 Noise maps for the Port of Los Angeles

This sub-section presents an overview of the Port of Los Angeles and noise mapping.

1.2.1 Overview of the Port of Los Angeles

The Port of Los Angeles was officially established in 1907 by a State Tidelands Grant to the City of Los Angeles and nowadays becomes the number one port by container volume and cargo value in the United States. The Port is administered for the City by the Los Angeles Harbor Department, which acts as a landlord and leases its property to various customers, who in turn operate their own facilities. The Port utilizes funds received from its customers (not taxpayers) for the maintenance and modernization of Port facilities. The Port is a critical hub in the international supply chain, and an integral part of the local, regional and national economy. According to a recent report published in its website, the Port generates, today, 919,000 regional jobs and $39.1 billion in annual wages and tax revenues. The Port serves as the Number One gateway for containerized cargo trade between Pacific Rim countries and the United States. Indeed, in calendar year 2007 the Port handled 8.4 million twenty-foot equivalent unit (TEU) containers. Major trading partners include China, Japan, Taiwan and Thailand, and top imports from these countries include furniture, apparel, electronic products, toys, cars and computer equipment.

The Port encompasses 7,500 acres of land and water and 43 miles of waterfront. 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. Indeed, the Port of Los Angeles is the #1 container port by volume 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 TEUs 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 following table lists container counts (TEUs) for the years of 2011 and 2012. Statistics for the recorded month are released on or around the 15th day of the following month.

Table 2. Container Volumes (TEUs) at the Port of LA

July	2012	2011	Change	Percent Change
Loaded Inbound[2]	371,859.15	357,667.70	14,191.45	3.97%
Loaded Outbound[3]	165,581.25	165,135.25	446.00	0.27%
Total Loaded	537,440.40	522,802.95	14,637.45	2.80%
Total Empty	188,934.85	165,522.60	23,412.25	14.14%
Total	726,375.25	688,325.55	38,049.70	5.53%
Calendar Year 2012 (to date)	4,736,579.10	4,455,552.95	281,026.15	6.31%
Fiscal Year 2013[4] (to date)	726,375.25	688,325.55	38,049.70	5.53%

[1]TEUs = Twenty-foot equivalent units, a standardized maritime industry measurement used when counting cargo containers of varying lengths.
[2]Inbound = Imported containers.
[3]Outbound = Exported containers.
[4]Fiscal Year = July 1 through June 30.

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. Table 3 provides the list of the terminals at the Port by cargo type inventoried:

Figure 1. Port of Los Angeles Terminals

Noise impacts at ports are expected to be significant and noise assessment as well as mitigation strategies will certainly be required. For this particular study, the impacts of noise at container terminals at the Port of Los Angeles will be investigated.

Table 3. List of Terminals at the Port of Los Angeles

Terminal	Location/Name
Container Terminals	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
Break-Bulk Terminals	Berths 49-53**:** PORT OF LOS ANGELES Berths 54-55: STEVEDORING SERVICES OF AMERICA (SSA) Berths 174-181: PASHA
Dry Bulk Terminals:	Berths 165-166: BORAX Berths 210-211: SA RECYCLING
Liquid Bulk Terminals	Berths 118-120: KINDER MORGAN Berths 148-151: CONOCOPHILLIPS Berth 163: NUSTAR ENERGY Berth 164: VALERO Berths 167-169: SHELL Berths 187-191: VOPAK Berths 238-240C: EXXONMOBIL
Auto Terminal	Berths 195-199: WWL VEHICLE SERVICES AMERICAS, INC.
Cruise Passenger and Ferry Terminals	Berths 91-93: WORLD CRUISE CENTER Berth 95: CATALINA EXPRESS Berth 95: ISLAND EXPRESS

The following table shows 25-year increments for the Port's Centennial (1907-2007).

Table 4. Twenty five-year increments for the Port's Centennial (1907-2007)

	1907	1932	1957	1982	2007
Cargo Value	$45.4 million[1]	$790.6 million	$1 billion	$9.4 billion	$238.4 billion
Cargo Tonnage	1.1 million tons	19 million short tons	24.1 million short tons	5.1 MMRT[2]	189.6 MMRT
Top Import	Lumber	Lumber	Copra (dried coconut)	Oil	Furniture
Top Export	Oil	Oil	Steel	Petroleum Coke	Paper Products
Top Trading Partner	Pacific Northwest	Japan	Japan	Japan	China

[1]Estimate

[2] MMRT=Million Metric Revenue Tons

Noise levels generated during the container terminal operations at ports vary depending on the type of equipment and the nature of the work being performed. In general, there are two major aspects of the noise arising from Container Terminal Operations at ports:

(i) Specific **penetrating noise sources**: these include warning sirens on cranes and straddle carriers, ship's horns sounded on departure and train crossing warning bells. The noise levels resulted from these sources usually have the greatest concern to residents, although they do not have much effect on measured noise levels due to their frequency and duration. This is a result of the audibility of these sources due to their tonal characteristics and intermittent operation.

(ii) **General plant noise** sources: Operation of Container Terminals at the Port of Long Beach involves the following main sources of general plant noise: gantry container cranes, ship generators, road trucks, trains, forklift, yard tractor. Several selected noise sources are discussed below.

- **Gantry Container Cranes:** Every container crane is equipped with a large electric motor located at high level which is used to lift the container up and down. The electric motor usually generates a high sound power level (approximately 110 to 115 dBA for a typical operation) and is the main noise source involved with the container crane. Penetrating noise sources associated with the cranes are the movement warning devices and the impact of containers on other surfaces.
- **Ship Generators:** These are large diesel generators that are used to produce the power required for onboard activities when ships are at berth. The noise levels resulted from these ship generators vary significantly from ship to ship and have been found to be in the range of 100 to 115 dBA (L_{eq}) sound power level. As a result, the Port of Long Beach is moving aggressively to outfit its container terminals with shore power. Shore power allows docked ships to plug into land based electric utility instead of burning diesel fuel to run their auxiliary engines, a source of pollution. By 2014, at least one berth at every container terminal will have shore power. By 2020, all container berths will have shore power.

Trucks and Trains: These are the two alternative methods of moving containers away and into the container terminal. A number of 'truck exchange areas' are located around the terminal for trucks to park in and load/unload their containers. The unloading of trains used to involve shunting onsite.

1.2.2 Noise mapping

Noise mapping or noise modeling is a method of presenting complex noise information in a clear and simple way either on a physical map or in a database. In other words, noise mapping is the geographic presentation of data related to outdoor sound levels and sound exposure with associated information on impact to the affected population. The noise mapping or noise modeling takes into account the contribution of all noise sources as well as the effects of obstacles and terrain. For large urban areas, it is possible to calculate noise maps using the available data on buildings, ground profile, road and rail traffic, and other industrial sources. The procedure of production of the noise maps (or noise modeling) can be summarized as follows: first, data for road and rail traffic as well as noise data for industry are collected; then, these collected data are used to create digital models of buildings, screens, and topography; finally, the noise levels are calculated using noise propagation models in order to create the noise contours for the maps.

At least two noise modeling software, i.e. CadnaA and SoundPLAN, are now available in Europe and they are capable of handling different noise sources including road, rail traffic and industrial equipment. In addition, they offer significant advantages in their fast processing speed over a virtually unlimited number of receivers, multiprocessor support, built-in CAD functionality, 3-D viewing, building façade noise predictions, professional graphics and GIS/CAD-compatible input and output. The United States lags behind the European countries in terms of noise mapping. In effect, the European Union directive 2002/49/EC makes noise mapping mandatory for cities (e.g. Paris and Brussels and major seaports such as Hamburg and Copenhagen) with at least 250,000 inhabitants, while noise mapping is currently not mandated by the U.S. federal or state governments. Noise studies in the U.S. are limited to highway, railway, or airport noise. The noise prediction models used in these studies are limited in scope and do not include noise from sources other than the infrastructure under study.

Data to be input: Before noise levels at ports can be accurately predicted, the necessary data to be input should be determined. For this particular project, the major input data include (i) source noise levels; (ii) ground topography; and (iii) operational activities.

(i) *Source noise levels*: The noise levels of major sources at the port such as ships, cranes, fork lifts, trucks/trains, and container handling equipment should be collected for establishing the sound power level of each source, from which the sound level at different distances can be calculated. The noise level collection can be conducted by either measuring on the site or obtaining from the manufacturers.

(ii) *Ground topography*: Before noise levels of different sources at the port can be determined, the ground topography (i.e. ground contours and buildings), which strongly affects sound propagation must be accurately provided. To obtain a sufficiently precise result, the ground contours should be established at 10-meter intervals.

(iii) *Operational activities*: The operational activities are the major noise sources to be needed for determining the overall noise as well as the port noise boundaries. Usually, the operational data must be predicted for future uses at the port, from which the port noise boundaries can be generated. For example, the number of ships that might visit is first predicted, then the volume of cargo (e.g. the number of containers that would be handled) can be estimated, and finally the number of straddle carriers and forklifts that would be in operation, and the number of trucks/trains required to move that volume of cargo to and from the port can be determined. Unless a reasonable estimate for the operational activities is obtained, the overall calculated noise will be inaccurate and the port noise boundaries will be in an incorrect position.

The above data (i.e. source noise levels, ground topography, and operational activities) is then input into a noise modeling software (e.g., CadnaA, SoundPLAN) to predict the noise levels over the area of interest and calculates the noise contours. Basically, the noise modeling software calculates the average noise from each source to a grid of receiver points, typically spaced 10 meters apart, for different periods of the day, taking into account the fact that many of the sources move over a wide area.

Use of the noise maps: The generated noise map can be used to study the noise impacts, to identify noise hot spots, to develop noise reduction measures, and to monitor trends in the environmental noise. For example, from the noise map of a port, the port authorities will be able to identify the current noise levels of areas where mitigation is needed, and where new and future development will have the greatest negative impact.

2.0 Research methodology

The research methodology to determine the noise impacts resulting from operations of the container terminals at the Port of Los Angeles includes the following tasks: (i) Surveying the Port to create an inventory of noise sources; (ii) Collecting data needed for developing noise maps; (iii) Creating a 3D computer model of the Port; (iv) Creating noise maps (i.e. noise models); and (v) Generating a noise map for the Port of Los Angeles using the software SoundPLAN.

2.1 Surveying the Port to create an inventory of noise sources

A survey on container terminals at the Port was conducted to determine representative locations in the terminals for collecting actual noise data. These locations (refer to Figures 2-8) 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
- Location # 9 includes Berths 121-131

It is noted that due to restrictions from the terminal operators of the Port, the research team was not permitted to access inside the terminals to collect noise data. In effect, the locations selected for data collection were outside the terminals but close enough to the various key noise sources such as the trucks, cargo handling equipment, and trains. They include truck entrances, areas next to the container yards where container handling activities take place, and also the railroads. The locations are scattered around the Port in order to give a reasonable sampling of the noise levels.

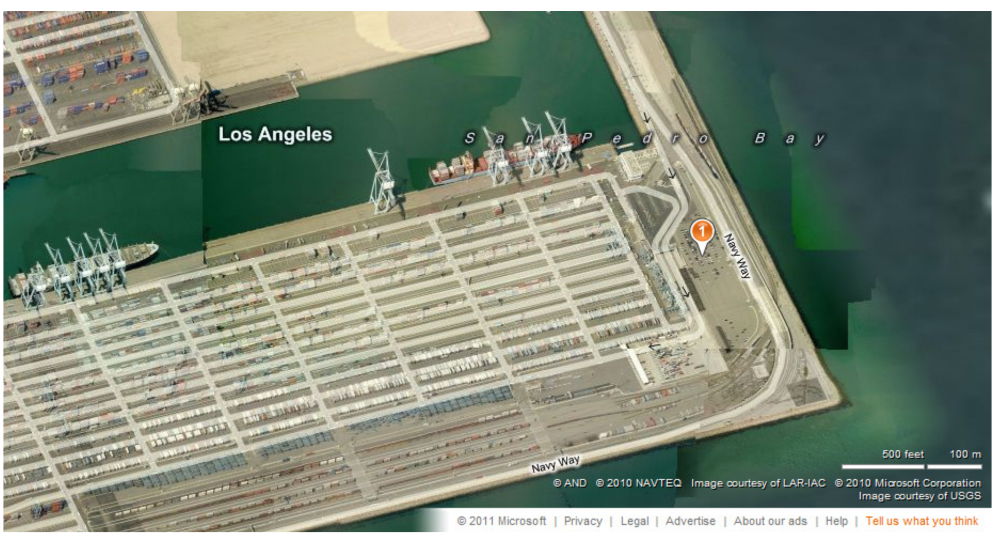


Figure 2. Location # 1 includes Berths 401-406

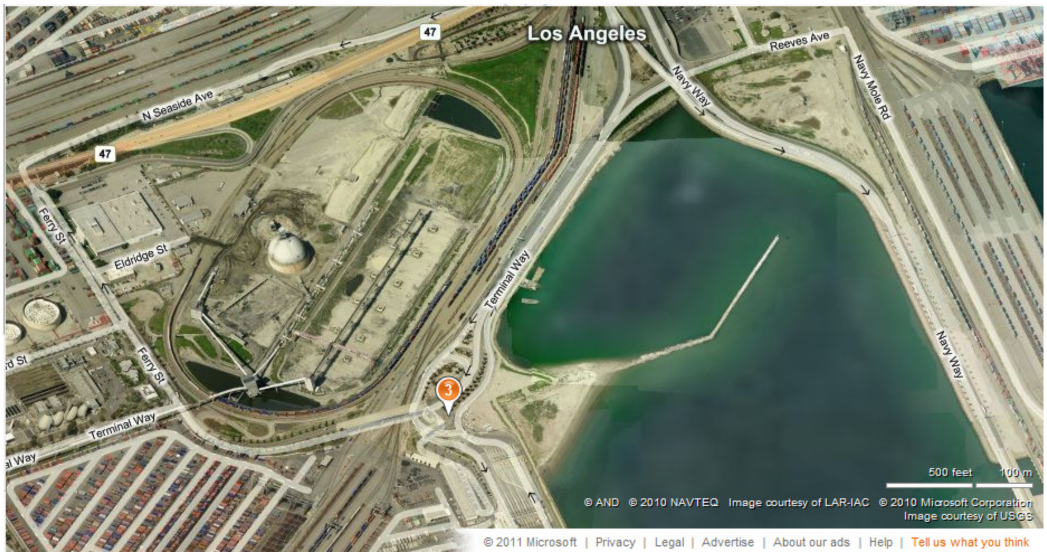


Figure 3. Location # 3 includes Berths 302-305

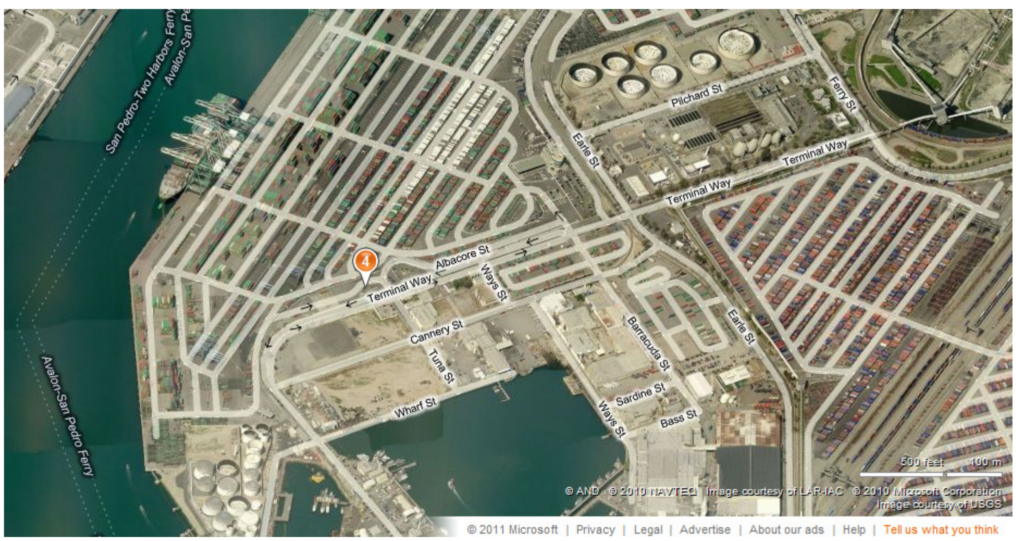


Figure 4. Location # 4 includes Berths 226-236

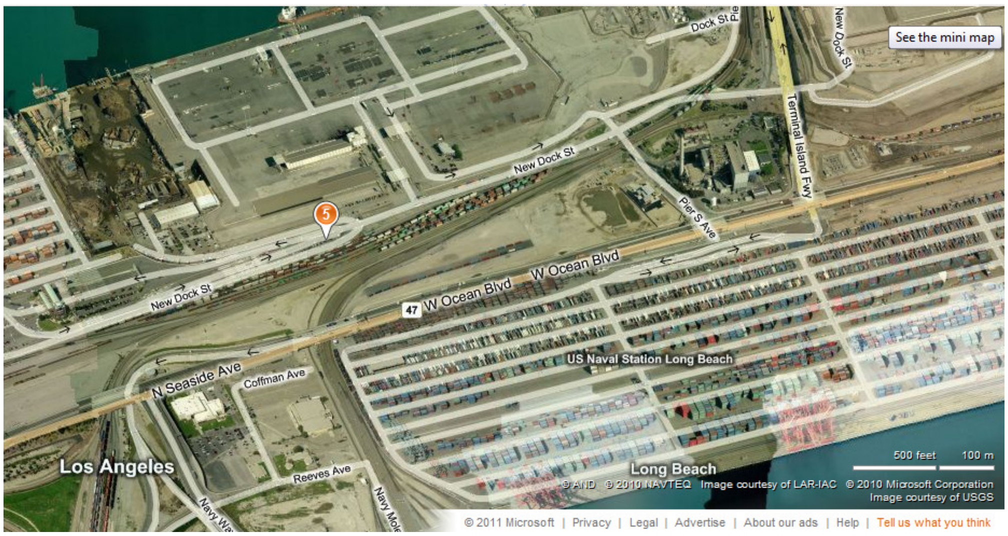


Figure 5. Location # 5 includes Berths 212-225

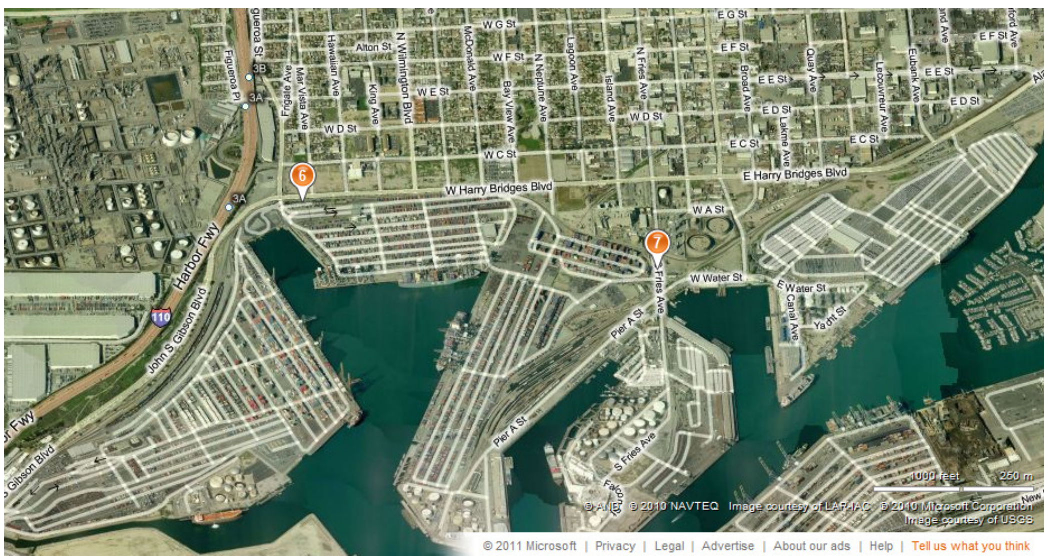


Figure 6. Locations # 6 & 7 include Berths 135-139

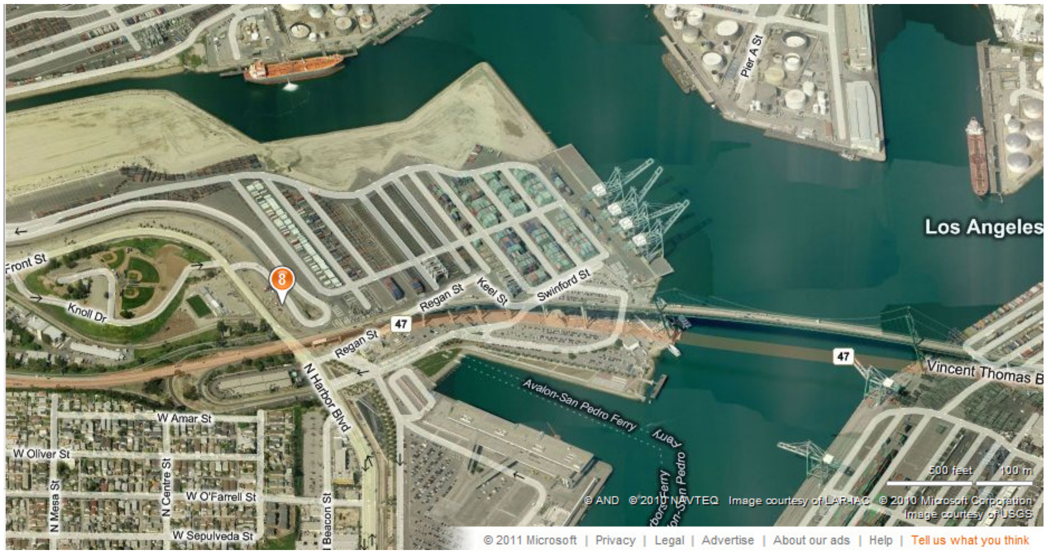


Figure 7. Location # 8 includes Berth 100

Figure 8. Location # 9 includes Berths 121-131

2.2 Collecting data needed for developing noise maps

The next task of this research project is to collect data needed for developing noise maps of container terminals of the Port. The data to be collected include: noise data; the information of operational activities at the Port; and the spatial information of the facilities as well as the ground at the Port, which will be presented below. Also, measurement tools will be discussed in this section

2.2.1 Noise data

Noise generated from port areas can be grouped into two categories: industrial noise and traffic noise.

Industrial noise: is generated from the industrial sources such as cargo/container handling equipment, cranes, vehicles, auxiliary equipment, etc. The data needed for modeling industrial noise include:

- Locations and heights of noise sources
- Working time periods (hours) of each source including days, evenings and nights
- Sound power level of each industrial source

Industrial noise data at the port can be collected by two methods: measuring noise levels directly on the site and extracting noise data from either manufacturer specifications (default noise levels of the equipment) or available noise source databases. In the first method, noise levels can be measured by using established techniques and specialized equipment/software. This measurement method usually involves time consuming and complicated techniques. Furthermore, in order to obtain a high accuracy, background noise should be completely excluded from the measurement. The second method of noise data collection using specifications and databases offers a straightforward but less accurate approach. Data collected from the second method need to be validated. The data validation can be performed by measuring noise levels of a small sample of the dominant sources which are selected from the complete noise data set.

Traffic noise: is resulted from transportation vehicles. The data required for modeling traffic noise are:

- Location of roads and road surface (e.g. asphalt, bricks)
- Number of vehicles (light, medium or heavy) per hour for each time period (day, evening, night), average speeds.
- Location of railways
- Number of trains of per hour for each time period (day, evening, night), average speed, rail support (wooden or concrete sleepers, etc) and data on rail track (joined rail, switches and crossings, etc)

2.2.2 The information on operational activities at the Port

The information on operational activities at the Port such as the number and locations of noise sources was collected for this study. Specifically, for each operational activity (e.g. truck and rail traffic), the number and locations of noise sources were recorded. The information on operational activities at the port can be gathered by recording data on the site or extracting data from the daily activity schedule provided by the port authority. The traffic and cargo volume will be used to determine the level of activities.

The information on operational activities at the port to be collected includes the following:

1) Number of trucks observed (loaded or unloaded), and whether they are incoming or outgoing relative to the truck entrance.

2) Number of cargo handling equipment in operation and the time they are active. The equipment includes RTG, yard tractors, top handlers, and side-picks.
3) The time the railway is active. The number of containers carried by the trains is also counted.

2.2.3 The spatial and geographical information of the Port

As they significantly affects the sound propagation, the spatial and geographical information of the Port and its surroundings need to be collected. This information is also needed for creating the 3D computer model of the Port, which is presented in Section 2.3. The spatial and geographical data collected include dimensions and elevations of terrain and buildings located at the port. In general, the spatial and geographical data required for 3D computer modeling include:

- Spot heights and contours
- Residential and industrial buildings (including heights and dimensions)
- Other obstacles in the study area (e.g. containers' formations)
- Locations of noise sources: industry, main roads, secondary roads and railways.
- Locations of noise sensitive areas (schools, hospitals, recreational areas)
- Ground surface characteristics

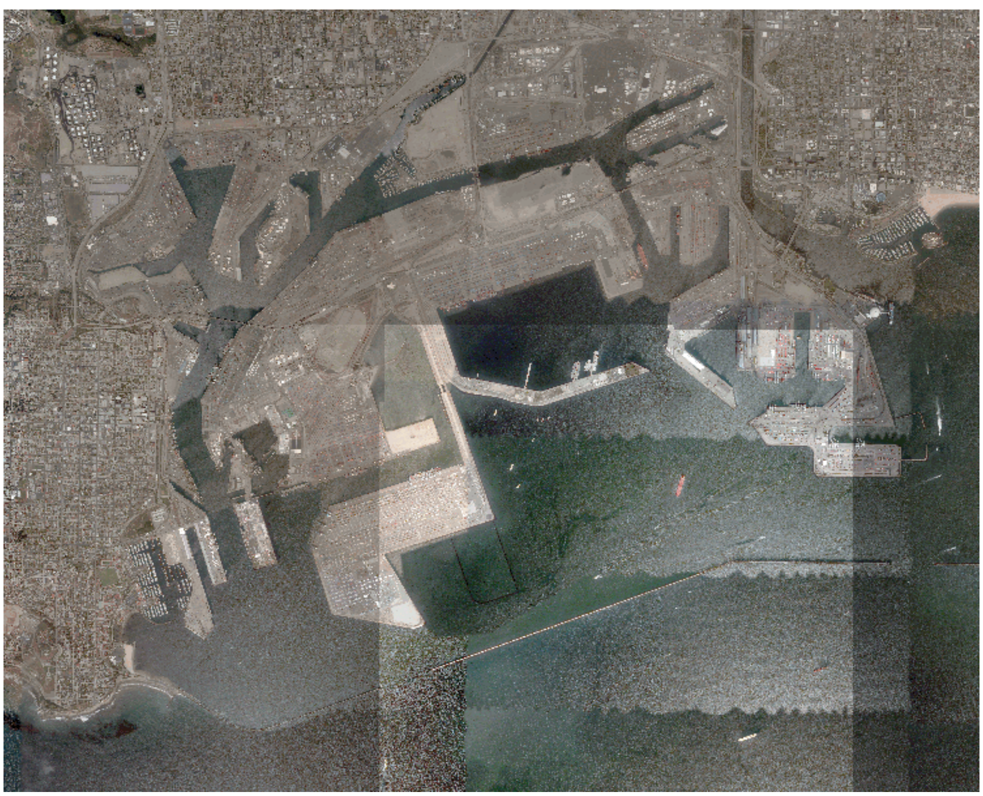


Figure 9. Topographic map of the Port of Los Angeles

Specifically, the spatial and geographical information collected for this study include: terrain elevations of the port; locations of the geographical and spatial features of interest; and heights of the buildings and other structures at the Port. For this study, the ground topography was obtained from the website of the US Geologic Survey. In the topographical map (Figure 9), the elevation contour lines had to be digitized manually.

2.2.4 Measurement tools

In this study, different measurement tools were used to collect noise data and the spatial/geographical information of the port, which are discussed below. Also, measurements of noise levels at the Port of Los Angeles are presented in this sub-section.

Tools for collecting noise data:

The primary tool used for noise data collection during this study was an integrating sound meter with data logging capability; i.e. Extech 407780 meter (see Figure 10). The noise is recorded through a microphone that can be attached directly to the sound meter or through an extension cord. The microphone is equipped with a wind filter to minimize the disturbance from wind during measurements. For this study, the sound meter was set to obtain the A-weighted average noise level (L_{eq}) for a period of 20 to 30 minutes, which was manually recorded by the research assistant on the site. In addition, the noise data log automatically stored in the meter can be downloaded to a computer for further analysis.

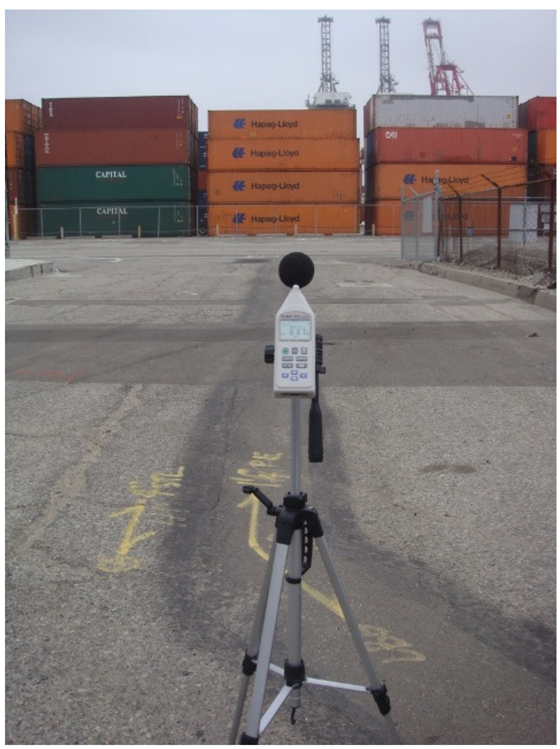


Figure 10 – Sound meter set up in the field

In order to reflect the variations in noise levels, the data collection should be conducted during both the peak and slow periods of operational activities at the port. In this study, the noise measurements were conducted from August 2011 through July 2012. Each measurement was made for 20-30 minutes during 4-6 hours per day. At the end of each measurement period, the noise levels were read from the meter and recorded by the research assistant. For a 6-hour/day session, there were up to 12 readings taken mainly during daily time from 8:00 AM to 4:00 PM, when most operational activities took place at the port. No readings were taken at night due to the safety issues. The research team created two sets of data needed for the noise study: the first set includes the average noise level (L_{eq}) and the second set contains the information about activities that contribute to the noise. For a convenience of recording, a data worksheet (see the sample copy available in Appendix B) was developed before hands.

In addition to the noise levels of the major sources at the port, the research assistant also reported any unexpected activities (e.g., construction work, train passing by, etc.) that might contribute to the noise volumes recorded and then should be excluded from the actual noise levels to ensure the data reliability. Also, the meteorological conditions of the port were also recorded at the start of each measurement using a portable weather station meter (see Figure 11). The weather data recorded include the temperature, humidity, wind direction, which are considered as parameters that may affect the noise propagation.

Figure 11. Portable weather meter

The collected data were then compiled to produce the charts of noise data analysis. Specifically, these charts represent the hourly, daily, and monthly averages for the noise levels and amount of activities for each location, which will be presented in Section 3 of this report.

Tools for collecting spatial/geographical information of the Port:

A high- resolution orthoimagery photo of the entire port (Figure 12), which can be obtained from the website of the US Geologic Survey (USGS) was the tool used to digitize the images of facilities such as roads, rails, buildings etc. located at the port, providing their spatial/geographical information. Such a digitalization was manually performed by the research team. It is noted that the higher resolution the image has, the more time it takes to complete the digitization process.

Owing to the features of geo-references (i.e. the coordinate systems, ellipsoids, and datums) available in the USGS orthoimagery photos, the digitized images can quickly line up during the digitization process. Similarly, the elevation data is geo-referenced. During the digitization process, Google, Bing, and AAA maps were used to identify the names of the roads so that they can be input into the computer model as well.

Figure 12. High resolution orthoimage of the Port

Figure 13. Details of ship at a terminal from the high resolution orthoimagery

While the USGS orthoimagery photos were used to digitize the image of the port providing 2D (two dimensional) information, Google Earth assisted in determining the heights of the buildings and major structures located at the port, which are needed for creating the 3D computer model of the port. It is noted that Google Earth incorporates the spatial data from CyberCity, a leading 3D (three dimensional) geospatial modeling company. To ensure the accuracy of the information, the heights of the buildings and major structures at the port were double-checked through field observation.

Measurements of noise levels at the Port

For this particular project, the noise levels at the Port of Los Angeles were measured using an integrating sound meter. Since noise levels can vary significantly over a short period, they are usually described as their average character or the statistical behavior of their variations. For instance, environmental sounds are described in terms of an average level that has the same acoustical energy as the average of all the time-varying events. This energy-equivalent sound/noise descriptor is called L_{eq}. A common averaging period is hourly, but L_{eq} can describe any series of noise events of arbitrary duration. The scientific instrument used to measure noise is the sound level meter. Sound level meters can accurately measure environmental noise levels to within approximately plus or minus 1 dBA.

The sound level meter used to measure noise levels at the Port was set to provide the A-weighted L_{eq} average noise for a measurement period of 20 to 30 minutes. The noise levels were recorded as a data log, which then can be downloaded into a computer for further analysis. Further details of the measurement procedure and collection of noise data will be discussed in Sections 2 and 3, respectively.

2.3 Creating a 3D computer model of the Port of Los Angeles

Before the maps of noise levels generated from the Port can be established, a 3D computer model of the area under study must be created. The 3D computer model of the Port was created by means of the digital images providing the spatial/geographical information together with the elevation data and the heights of buildings/structures at the Port.

Figure 14 shows the complete digitized spatial model of the Port. It includes the major buildings and structures, as well as roads and railways that are relevant to this study. The grey and red lines represent the roads and rails respectively. The buildings and structures are in green. The upper boundary of model is slightly north of Anaheim St. The boundary is the edge between the Port of Long Beach and the Port of Los Angeles. Note that the roads and buildings around downtown Long Beach are not digitized since the container activities do not extend to that area, although the elevation data is included. The area however is included in the noise propagation simulation. The digital spatial model with elevation contour can be displayed in 2D (Figure 15) or 3D (Figure 16).

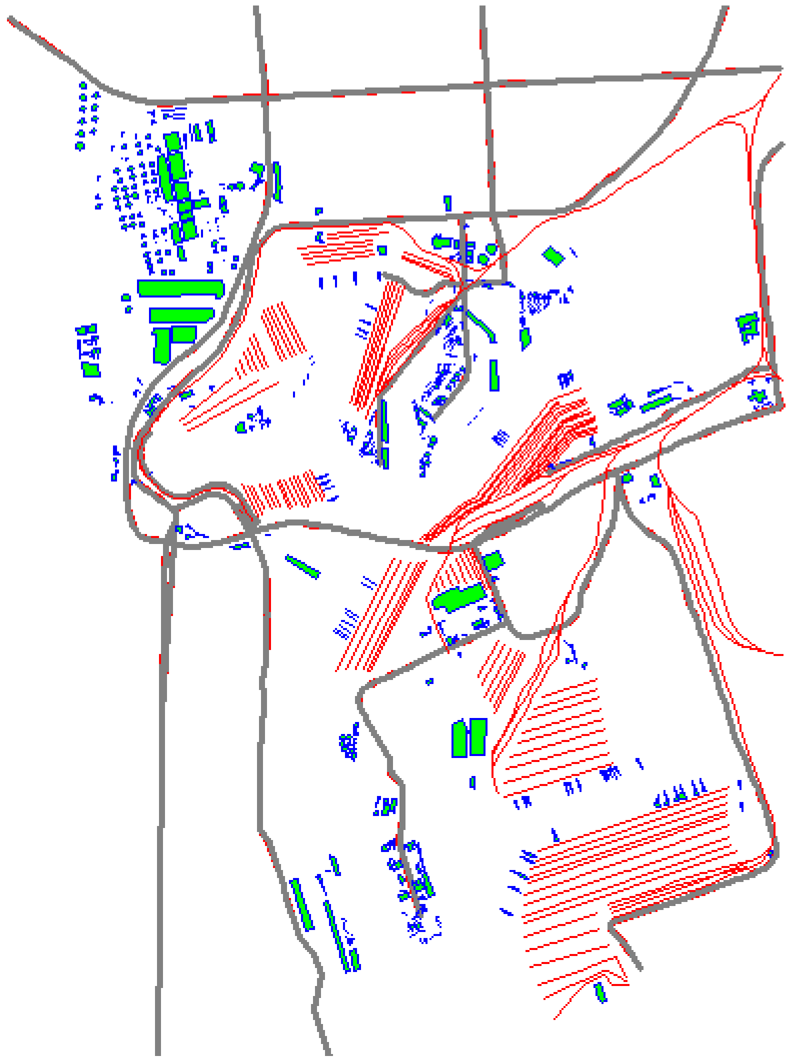


Figure 14. Digital spatial model of the Port

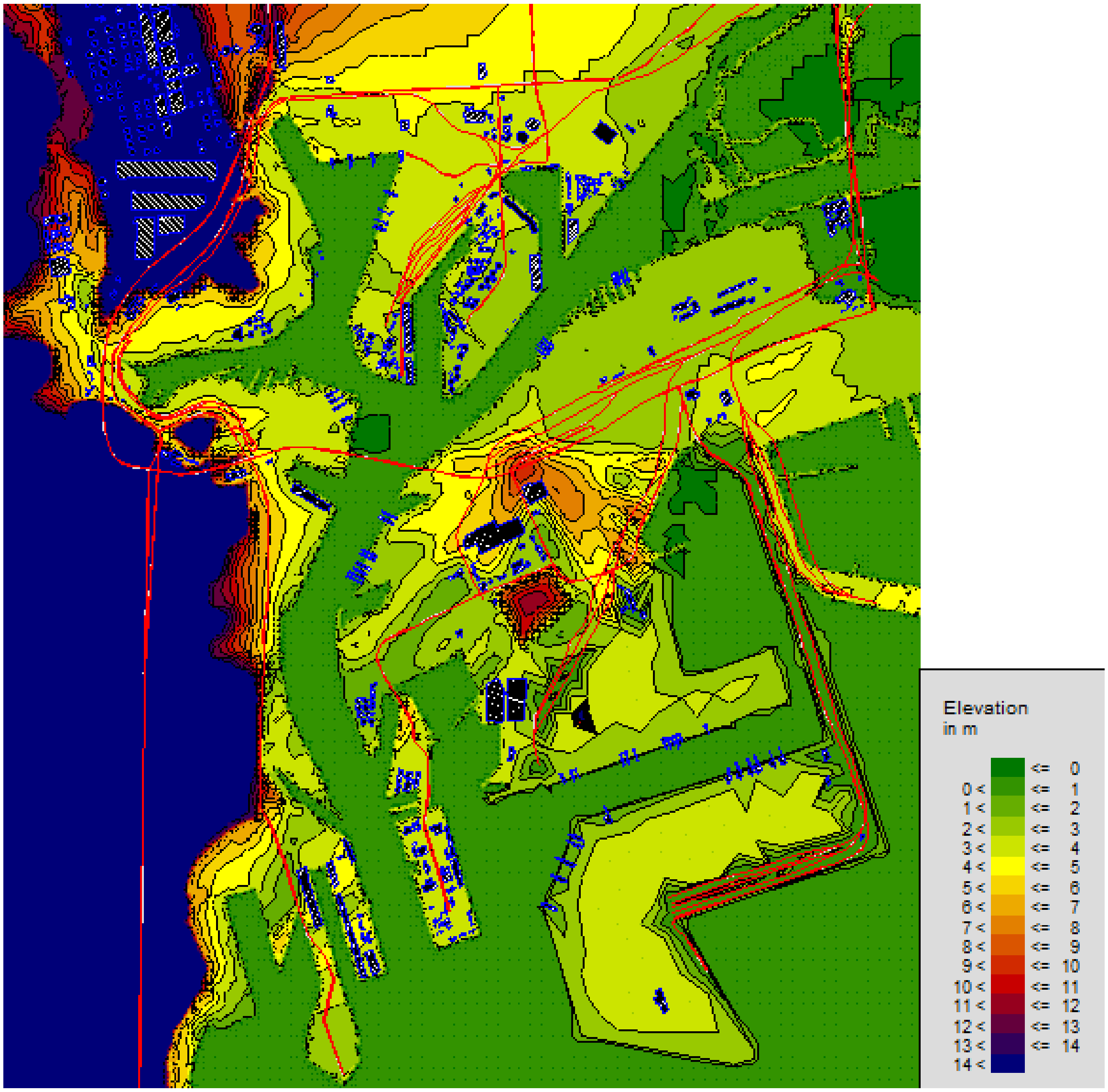


Figure 15. Two-dimension digital spatial model of the Port with elevation contour

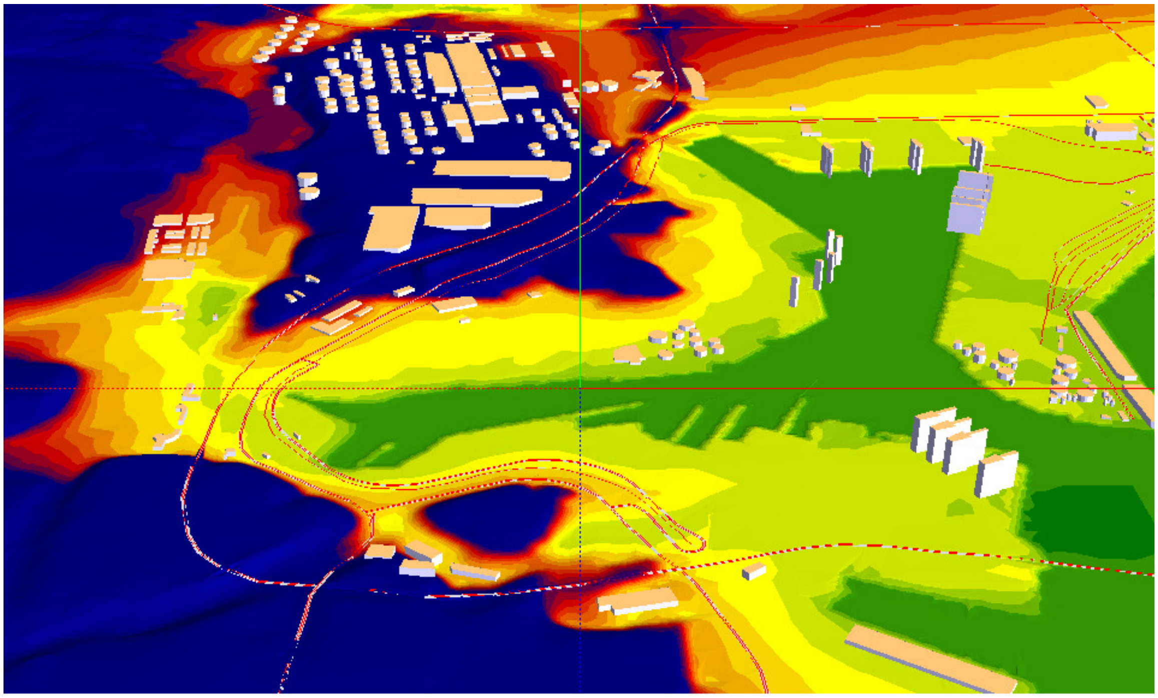


Figure 16. Three-dimension digital spatial model

2.4 Creating noise maps (i.e. noise models)

Noise maps of a particular area under study can be generated from a computer noise modeling software in the following steps:

- First, the digital 3D spatial and elevation model of the area is created in the computer software.
- Next, all the noise sources (e.g. road, rail, industrial equipment etc.) at the port are added to the model. The noise sources at the Port 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 which comprises of 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 can not be separated from each other.
- The following 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.

The noise model is used to predict the noise levels at various locations by taking into account all the noise sources. It also includes the effects of distance, shielding from barriers, and meteorological conditions when calculating the noise propagation. The results are then shown either graphically in the form of noise maps or numerically in detailed lists.

2.5 Generating a noise map for the Port of Los Angeles

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. Following the steps of generating a noise map presented above, the geographical information and the digitized spatial data were first imported into SoundPLAN to obtain a 3D computer model of the Port. The noise sources (e.g. container trucks, trains, ships, and cargo handling equipment including cranes, forklifts/sidepicks/top-handlers, and yard tractors) and activity information are then added to complete the noise model. Finally, the noise model can be used to generate the noise distribution and the noise map. The generation of the noise map often involves the calculations of noise propagation and noise volumes of container activities, which are discussed below.

Calculating noise propagation: The SoundPLAN software provides various standards for calculating the noise propagation. In this study, the RLS-90, Schall-03, and ISO 9613-2 were used for calculating the road, rail, and industrial noise respectively. They were selected because they have been tested thoroughly in SoundPLAN. They are also more optimized in SoundPLAN compared to the other standards and require less simulation time. For example, the simulation using RLS-90 is 75% faster than NMPB-96, and Schall-03 is very much faster than RMR-2002. In this large scale simulation, every effort is made to reduce the simulation time, keeping it under 8 hours. SoundPLAN also includes a distributed computing feature which allows the computation to be shared among available networked computers, which significantly reduces the computation time. Once the simulation is complete, SoundPLAN has extensive graphics capability to display the noise map results in a regular color map, or in 3D or animated. The results can also be displayed in detailed lists.

Calculating noise volume of container activities: The volume of noise generated by the container activities is determined by the quantity of each noise source and their noise power and characteristics. The contribution of the noise source to the overall noise distribution then depends on the location of the source and their movement pattern, if mobile, plus the surroundings. So, the noise characteristics and the operational information of the sources need to be input into the noise model. Below are the discussions on modeling the noise emissions from trucks/trains and ships/cargo handling equipment.

Trucks

For the trucks, the calculation standards have built-in assumption on the noise emission characteristics of the vehicles, so only the operational information is required.

The RLS-90 standard is used to calculate the noise from the truck traffic. The standard allows the simulation of road noise by modeling standard vehicle types such as cars and trucks. In this study, we are focusing on the container activities where only trucks are involved in the movements of containers on the road. Therefore, cars are excluded in the calculations. The parameters required for the model include the number of trucks per hour and their speed for each road segment used by the trucks in hauling containers in and out of the each terminal. The Emission Report contains the average truck numbers for each of the major roads for different period of the day. These are adjusted using the actual truck data collected at the gates. The resulting number of trucks for each pier for different time period is shown in Table 5 below.

Table 5. Number of trucks by time period for each terminal (derived from field data and Air Emission Report)

Berth	AM (6-9am)	MD (9am-3pm)	PM (3-7pm)	NT (7pm-6am)
401-406	715	4593	2037	2304
302-305	242	1557	690	781
226-236	429	2754	1221	1382
212-225	354	2275	1009	1141
135-139	180	1155	512	579
100	265	1702	755	854
121-131	321	2061	914	1034

The truck routes are obtained from the field and the data is then compiled for each road segment and entered into the model.

Trains

The Schall-03 standard is used to calculate the noise from the train activities. The information needed for the calculations are the number of trains per day, the length of the train, and the speed. The standard also takes into account the different noise level for different types of trains such as express, freight, commuter trains etc. Freight train is selected for this calculation. The average number of trains per day carrying containers and the average length of the trains are obtained from the Air Emission Report. The number however is for the twin ports. So, the average container volume for each port is used to divide the train numbers between the two ports, with 22 going to POLA. Next, the 22 trains are then distributed among the different container terminals depending on their cargo volume. The truck count recorded in the field for each terminal, which is a good estimate of the cargo volume, is used for this purpose. Table 6 shows the data for the train activities. The information is entered for each rail segments serving the different terminals. The average speed of the trains is assumed to be 20mph.

Table 6. Average number of trains per day for each terminal
(derived from Air Emission Report and truck data)

Berth	Average # of trains per day	Average length of train (meters)
401-406	6	2290
302-305	2	2328
226-236	4	2059
212-225	3	2268
135-139	2	1727
100	3	1697
121-131	3	2055

It is noted that the standard requires the number of trains to be an integer value. So, the number is rounded to the nearest integer and the length of the train is adjusted proportionally so that the noise effect remains the same.

<u>Cargo handling equipment</u>

The ISO 9613-2 standard is used for calculating the noise from the ships and the cargo handling equipment. Since it is a general standard, the noise power and spectrum of the source and its operational information need to be provided. In this study, due to restrictions, it was not possible to measure the noise characteristics of these sources in the field. So, the noise database, SourceDB, is used instead. SourceDB is an industrial noise database which contains the noise characteristics of approximately 1,100 sources in over 70 different industries including those needed for our study. The database was developed for the EU IMAGINE (Improved Methods for the Assessment of the Generic Impact of Noise in the Environment) project and has been used in the EU NoMEPorts (Noise Management in European Ports) noise mapping activity which is similar to our project. The sound characteristics are available for all the sources needed in this study: RTG cranes, forklifts/sidepicks/top-handlers, yard tractors. The spectrum is specified in 1/3 octave band from 25Hz to 10kHz. To reduce the calculation time, the forklifts/sidepicks/top-handlers are grouped together due to their similarity. Figure 17 shows the sound power and spectrum of the various noise sources.

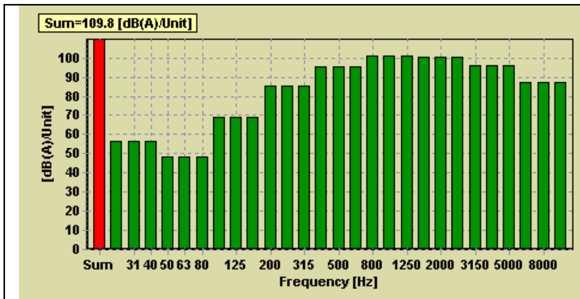
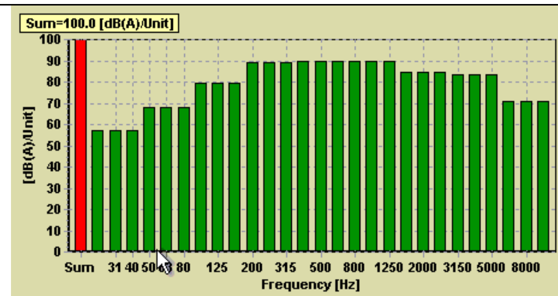
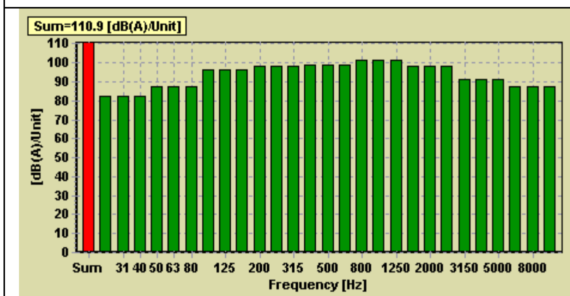
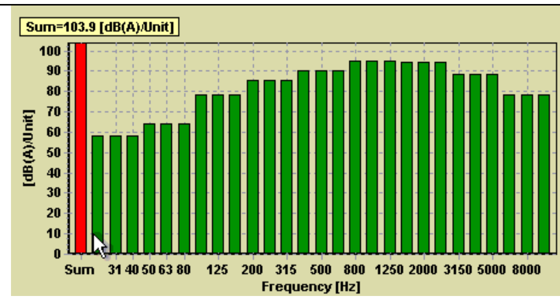
 Sound power and spectrum of RTG crane	 Sound power and spectrum of dockside crane
 Sound power and spectrum of forklift	 Sound power and spectrum of yard tractor

Figure 17. Sound power and spectrum of the various noise sources

Due to restrictions, the activities for the cargo handling equipment could only be recorded for a few of the piers and the data covers only a part of the overall activities. So, instead the operational information for these sources is derived from the air emission report and then adjusted using the field data.

The air emission report lists the make and model of each piece of cargo handling equipment (forklift, RTG crane, side-pick, top handler, yard tractor) in use at each terminal, and their annual hours of operation. Once again, the values are scaled to the current year's level using the cargo volume statistics and then adjusted for each pier using the observed truck activities as indicator for the cargo volume. The following is the resulting data. The final values are shown in Table 10 as the number of equipment active per hour for each pier for different time period. The same time distribution from the truck data is used here to divide the activities into the different time periods.

To complete the calculation, the locations of the sources need to be specified. Line sources are used to represent the ships and the cargo handling equipment. The forklifts, RTG cranes, and yard tractors will be located in the container yard; several line sources are needed depending on the number of rows of containers in the yard. The line sources are shown in red in the model of the port (Figure 18). Each line represents just one type of source. So the activity data in Table 7 needs to be divided by the number of lines representing the source type in the pier. This value is then entered for that line, together with the power and spectrum of the source type.

Table 7. Number of cargo handling equipment active per hour by pier and time period (derived from Emission Report and truck data)

RTG Cranes				
Berth	AM (6-9am)	MD (9am-3pm)	PM (3-7pm)	NT (7pm-6am)
401-406	2.0	6.0	4.0	2.0
302-305	1.0	2.0	1.0	1.0
226-236	1.0	4.0	3.0	1.0
212-225	1.0	3.0	2.0	1.0
135-139	0.0	2.0	1.0	0.0
100	1.0	2.0	2.0	1.0
121-131	1.0	3.0	2.0	1.0
Forklifts/side-picks/top-handlers				
Berth	AM (6-9am)	MD (9am-3pm)	PM (3-7pm)	NT (7pm-6am)
401-406	10.0	32.0	21.0	9.0
302-305	3.0	11.0	7.0	3.0
226-236	6.0	19.0	13.0	5.0
212-225	5.0	16.0	10.0	4.0
135-139	3.0	8.0	5.0	2.0
100	4.0	12.0	8.0	3.0
121-131	4.0	14.0	9.0	4.0
Yard tractors				
Berth	AM (6-9am)	MD (9am-3pm)	PM (3-7pm)	NT (7pm-6am)
401-406	38.0	123.0	82.0	34.0
302-305	13.0	42.0	28.0	11.0
226-236	23.0	74.0	49.0	20.0
212-225	19.0	61.0	40.0	17.0
135-139	10.0	31.0	21.0	8.0
100	14.0	45.0	30.0	12.0
121-131	17.0	55.0	37.0	15.0

Once all the data are entered in the model, the noise maps for port can be generated. They are shown in Section 3.

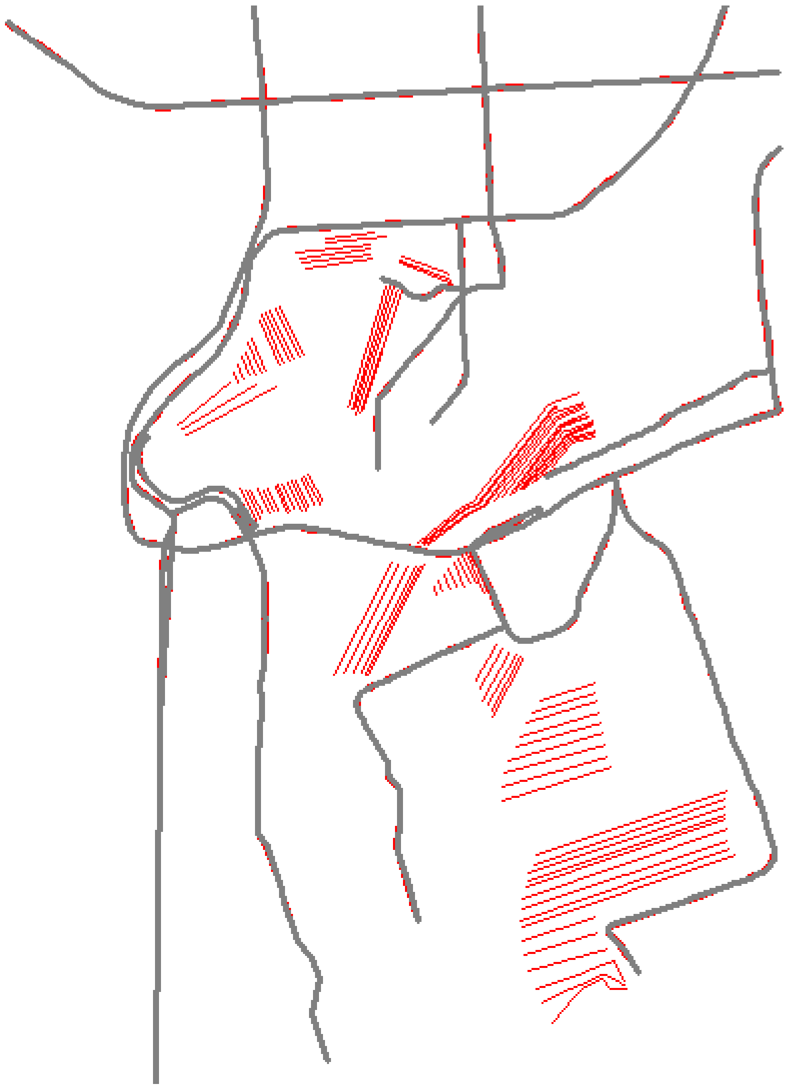


Figure 18. Map of ship and cargo handling locations.

3.0 Research results

This section highlights several selected results on noise studies from this project. Specifically, the research results to be discussed include: Noise distributions; Noise maps for the Port; and Evaluation of noise impact using noise maps.

3.1 Noise distributions

The noise and activity information was collected at 7 different locations around the Port (see Figure 2) for 4 to 6 hours per day, almost every weekday from July 2011 to July 2012, as mentioned in Section 2. Each measurement was taken for about 20 to 30 minutes and then normalized to an hour. The data was then compiled into hourly, daily, and monthly averages. The noise level is measured in dB(A). The truck activity is quantified as the number of truck movements per hour. The annual average value of the measured noise can be used to validate the noise map. The measurement locations were spread around the port in order to get a reasonable sampling. In addition to the annual average noise, the calculated hourly, daily and monthly noise averages are also useful as they provide insights into the noise variation. They can be used to supplement the noise maps which only show the annual average noise.

The truck count collected at each location was used to scale the activity data from the port emission report in order to generate the noise map. More specifically, the emission report's truck, train, cargo-handling activity values were scaled to the current year's level using the cargo volume statistics and then adjusted for each location using the observed truck activities as indicator for the cargo volume. . The details had been discussed in the previous section.

3.1.1 Hourly noise and activity distribution

The average hourly noise measured at each location is shown in Figure 19. Looking at the average for all the locations (indicated as the green line), it can be observed 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 is consistent with the operating characteristics of the container terminals at the port.

Looking at each location, it can be seen that the highest noise is at location 8 around 9am (76.9dB) and lowest noise is at location 3 around 1pm (65dB). Location 6 experienced the largest variation throughout the day (3.2dB), while locations 8 has the smallest variation, 1.2dB. For the locations near the truck entrances such as locations 3 and 5, there is a good correlation between the noise levels and the truck activities.

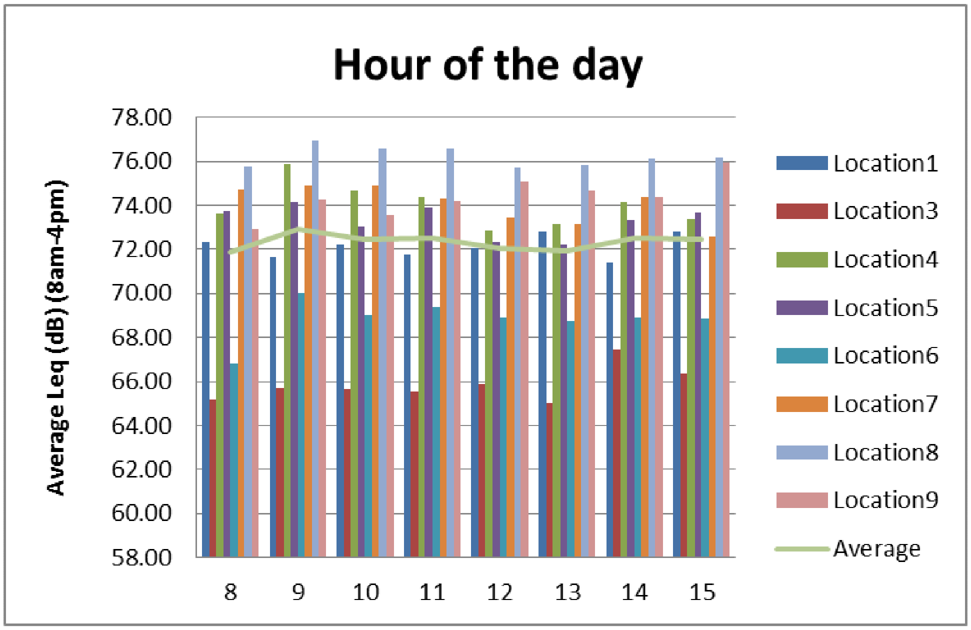


Figure 19. Hourly noise distribution for each location and the average

The average number of truck movements observed at each location per hour is shown in Figure 20. From this figure, the average for all the locations (indicated as the green line) indicates that the lowest truck activity is around noon time (386 trucks/hr). The peak truck activity is around 2pm (699 trucks/hr).

Also, it can be seen that location 1 has the highest truck activity around 1pm (1182 trucks/hr). The same location has the next highest truck activity around 11am with 1176 trucks/hr around 1pm.

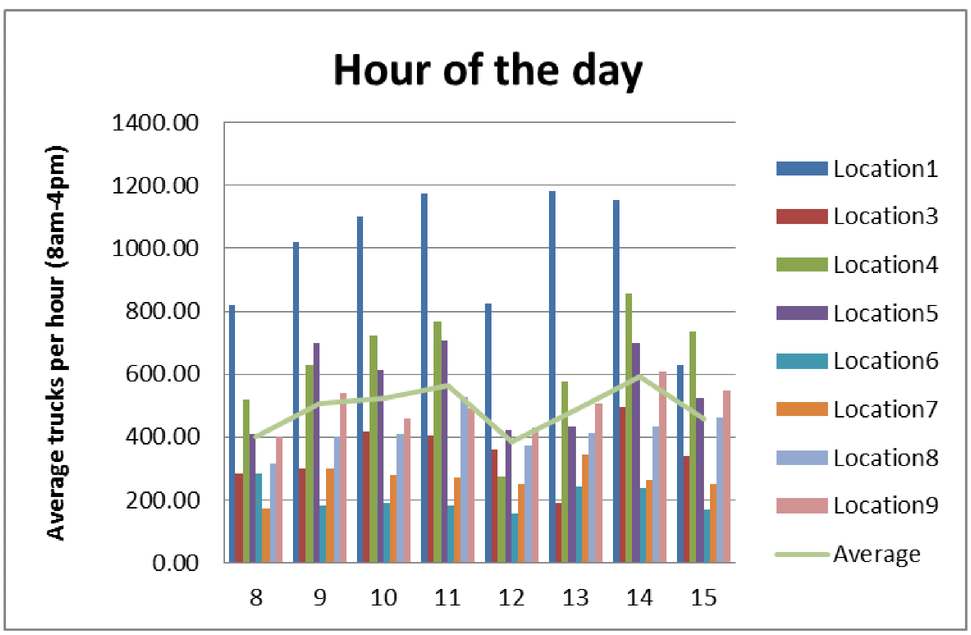


Figure 20. Hourly truck activity for each location and the average

3.1.2 Daily noise and activity distribution

From the hourly data, the daily averages are obtained for the noise and activities. For ease of comparison, the same unit of measure per hour is used for the activities, e.g. number of trucks per hour. Since the data is only collected during a short period of the day, the use of a 'per day' measure, such as number of trucks per day, would not be appropriate.

The average daily noise at each location is shown in Figure 21. Looking at the green line which indicates the average for all the locations, it can be observed that the average noise level has a slight peak on Friday (72.7 dB), but varies only by 1.1dB throughout the weekdays. The lowest noise is on Wednesday (71.6 dB).

In regard to noise at locations, it can be seen that the highest noise is found at Location 9 on Thursday (76.9 dB) and the lowest noise on a weekday is at location 3 on Monday (65.3 dB). Location 7 experienced the largest variation throughout the weekdays (3.7 dB), while Location 4 has the smallest variations, 1.2dB.

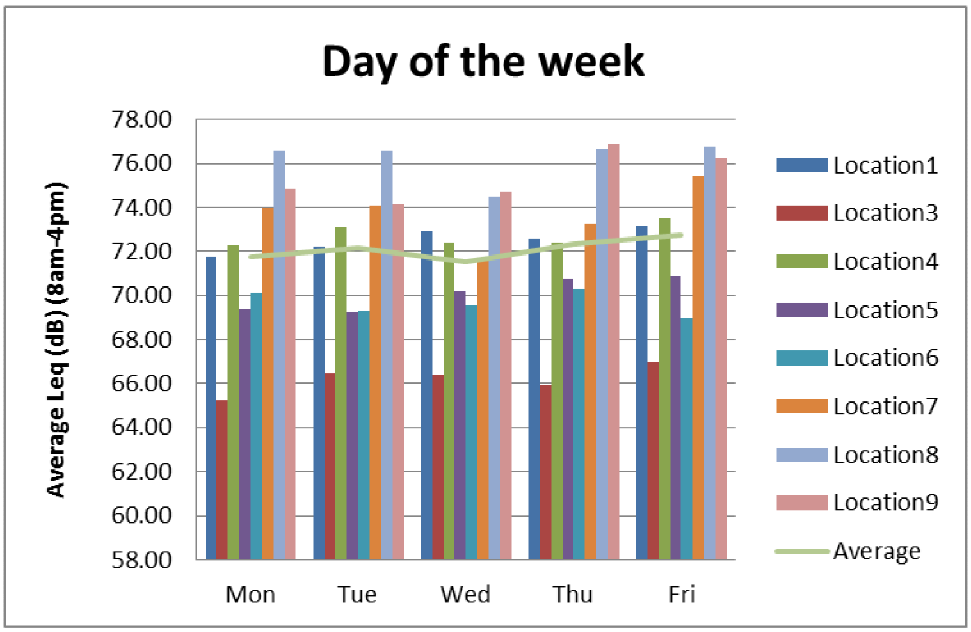


Figure 21. Daily noise level for each location and the average

The daily truck activity at each location is shown in Figure 22. The average for all the locations (represented by the blue line in the figure) shows that the highest truck activity is on Wednesday (327 trucks/hr) and the lowest is on Monday (267 trucks/hr), for weekdays. Regarding the truck activities at locations, it can be seen that location 1 on Wednesday has the highest truck activity (745 trucks/hr). The second highest one is Location 1 on Friday with 691 trucks/hr.

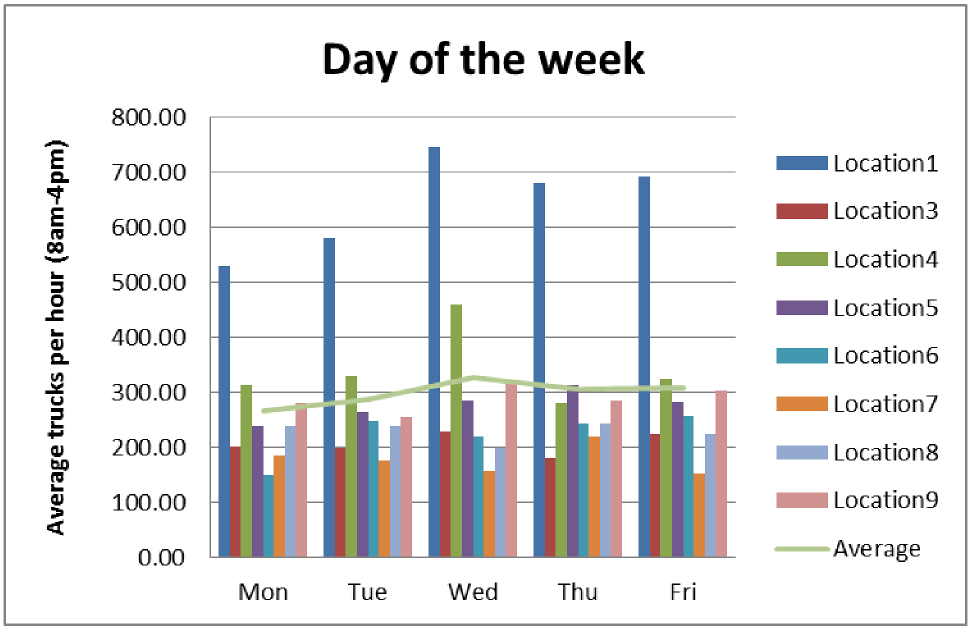


Figure 22. Daily truck activity for each location and the average

3.1.3 Monthly noise and activity distribution

The monthly averages are calculated for the noise and activities for the months of July 2011 through July 2012.

The average monthly noise at each location is shown in Figure 23. Looking at the green line which indicates the average for all the locations, it can be observed that the noise peaks are in July through September (73.6-73.9 dB). The lowest noise is in December (70.7dB).

In addition, it can be seen that the highest noise is at Location 4 in September (78.4dB) and lowest noise is at location 3 in December (63.7dB). Location 5 experienced the largest variation throughout the months (7.6dB), while Location 1 has the smallest variation, (3.1dB).

The monthly truck activity at each location is shown in Figure 24. Looking at the blue line which represents the average for all the locations, it can be observed that the average truck activity is highest in July (353 trucks/hr) and lowest in September (188 trucks/hr). Looking at each location, it can be seen that location 1 has the highest truck activity in June and July (721 and 746 trucks/hr).

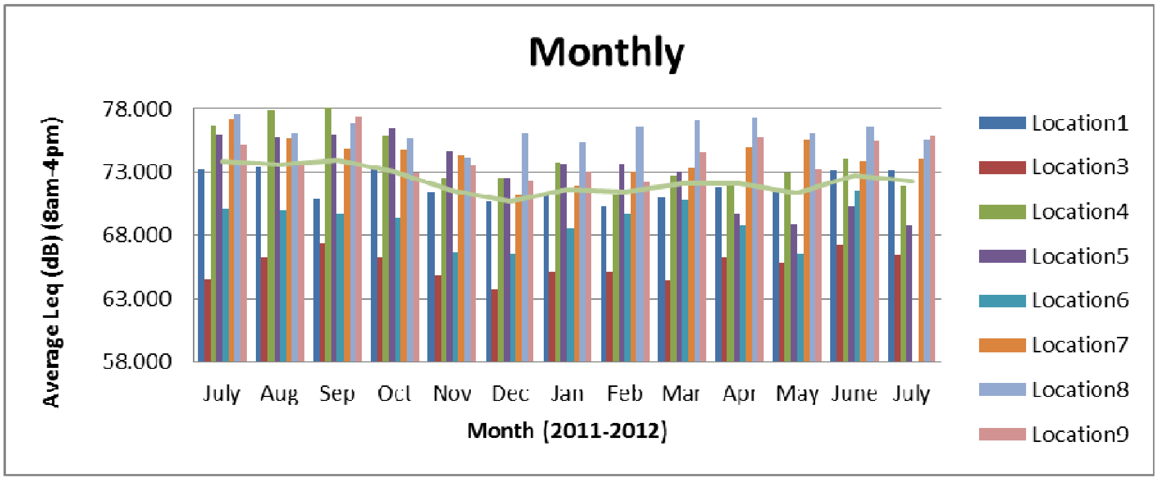


Figure 23. Monthly noise level for each location and the average

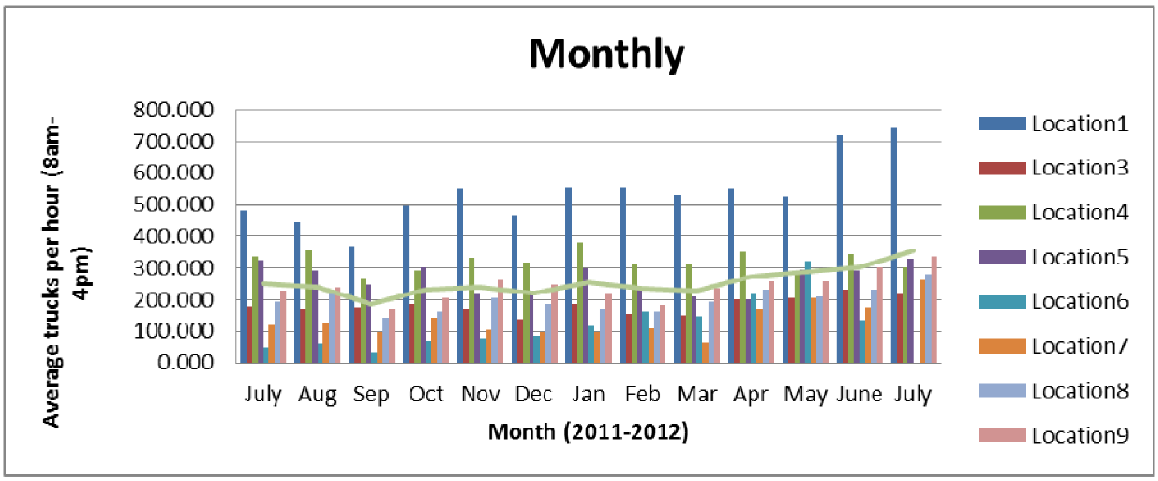


Figure 24. Monthly truck activity for each location and the average

3.1.4 Overall noise and activity distribution

By taking the average of the monthly data, the overall averages are obtained for the noise and activities. The average noise level for each location is shown in Figure 25. It can be seen 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.

The average truck activity for each location is shown in Figure 26. It can be seen that Location 1 has the highest truck activity (538 trucks/hr), following by Location 4 (322 trucks/hr) and Location 5 (267 trucks/hr). This overall truck activity data is a good indicator of the cargo volume of each container terminal for the current year and is used to adjust the data for the noise map calculation.

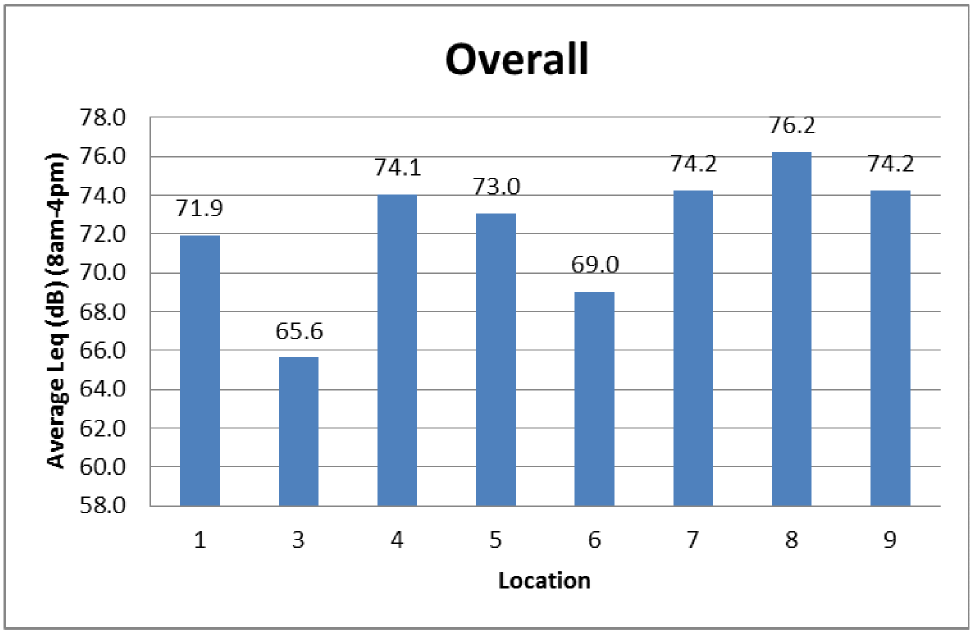


Figure 25. Overall average noise level for each location

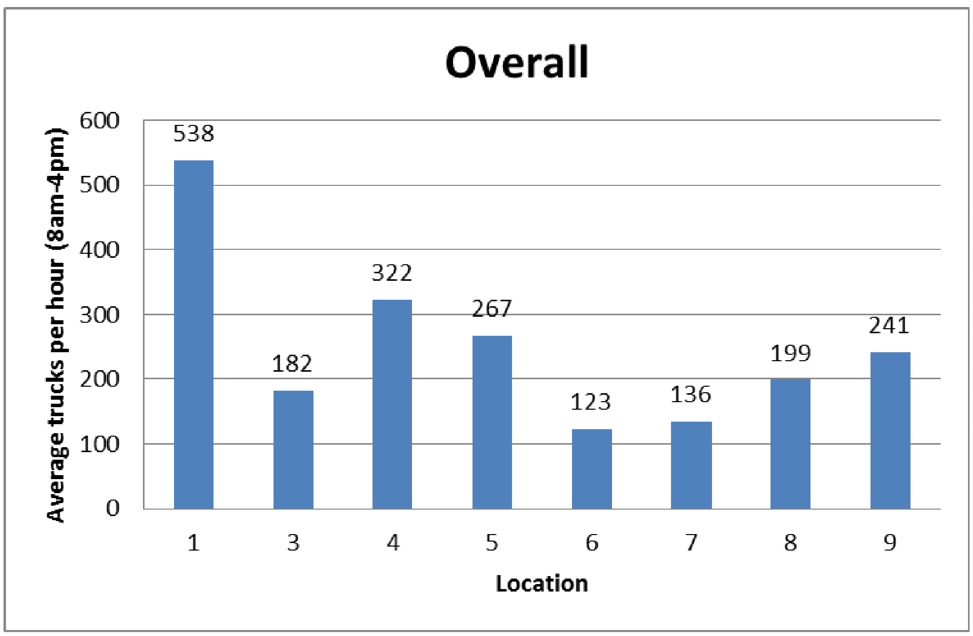


Figure 26. Overall average truck activity for each location

3.2 Noise maps for the Port of Los Angeles and validation of the results

The overall noise maps of the Port are shown in Figure 27 and Figure 28 respectively for the day period (6am-10pm) and night period (10pm-6am).

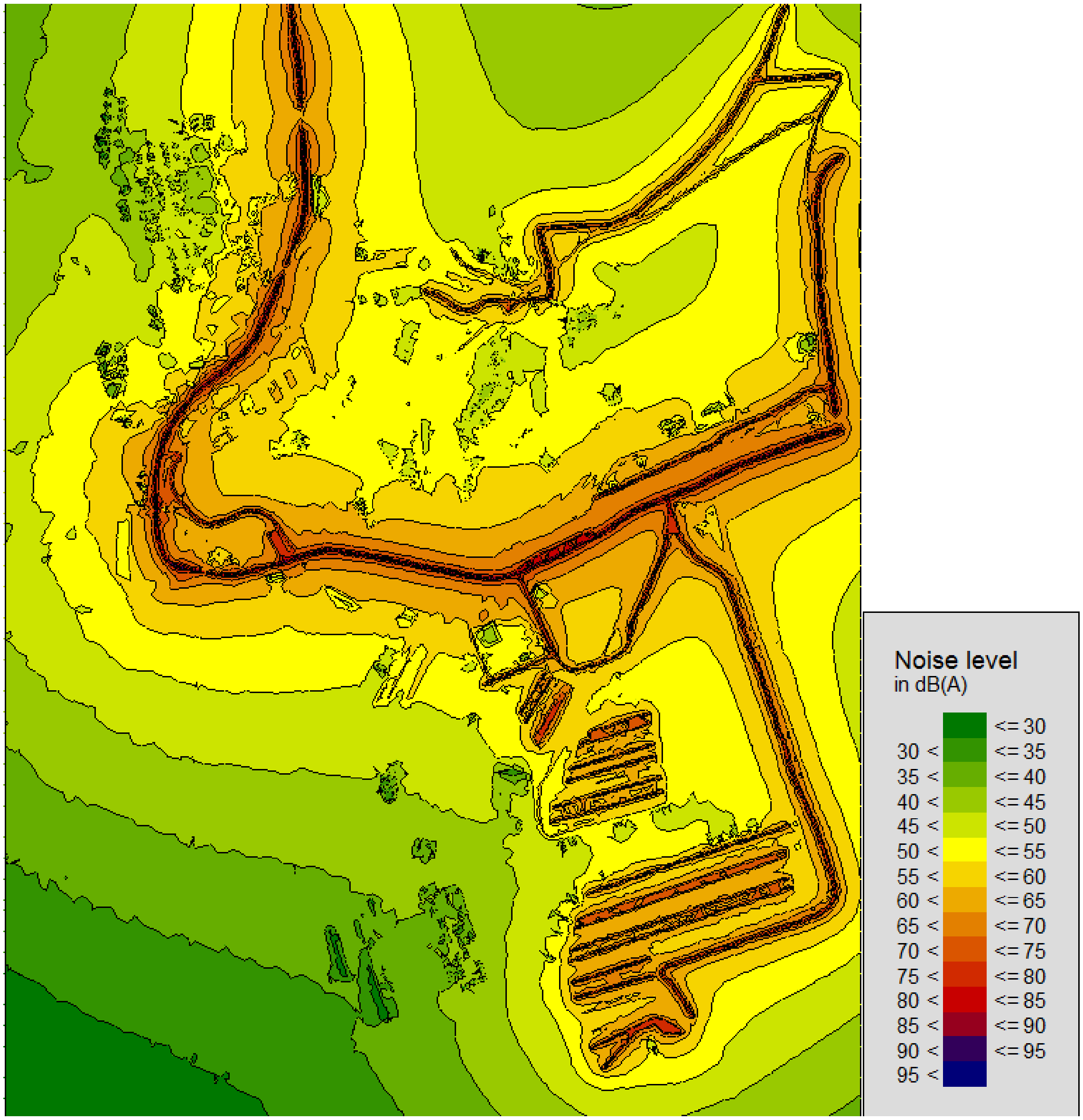


Figure 27. Overall noise map for day period (6am-10pm)

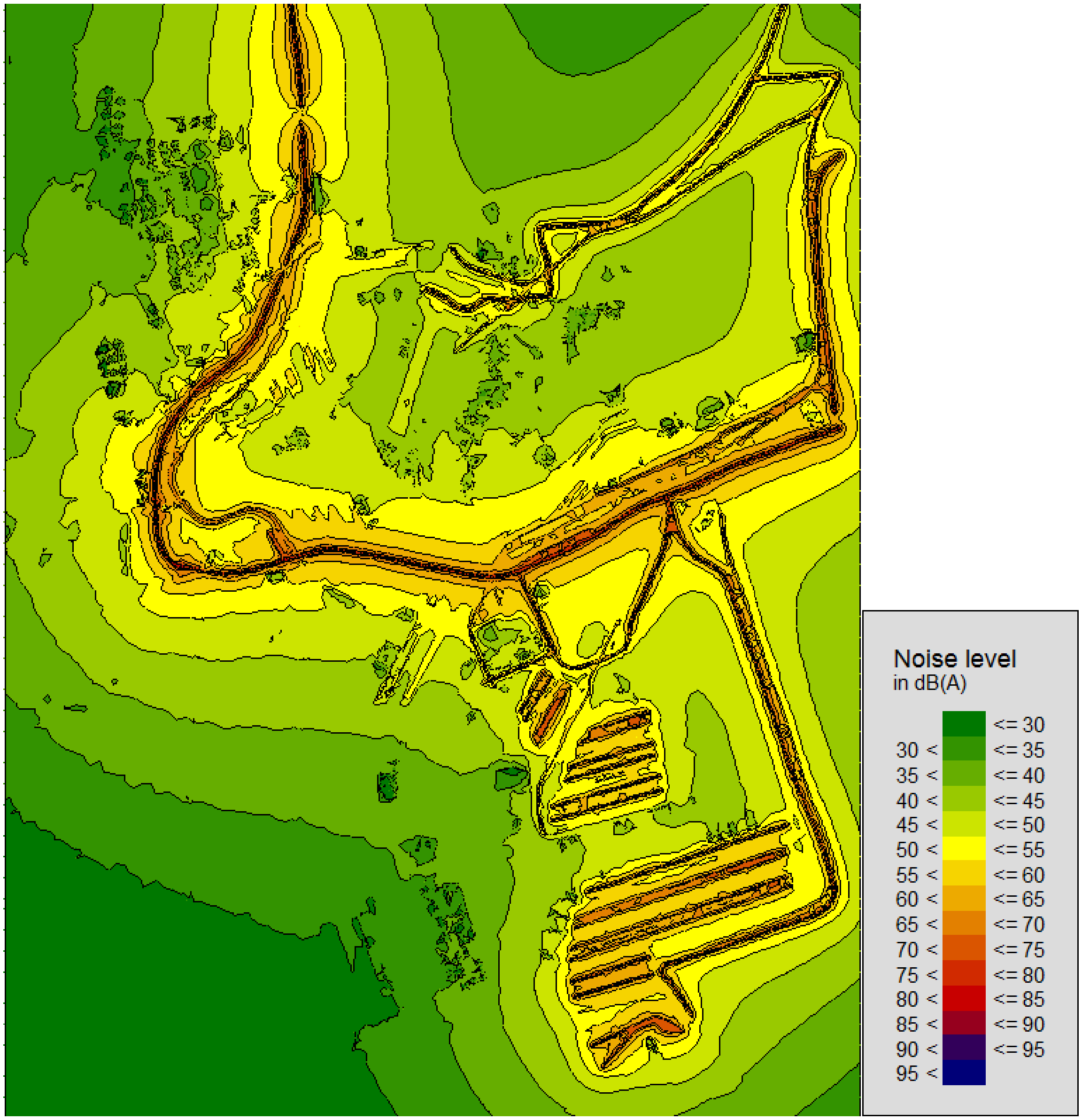


Figure 28. Overall noise map for night period (10pm-6am)

The result from the day period noise map is validated using the average noise measurement for each of the location. The comparison of noise levels given from the noise map with average noise levels measured from the field is shown in the table below.

Table 8. 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

It can be seen that the differences are within the acceptable range for all locations except Location 3. These locations have few non-container related activity sources. So the noise map results are close to the actual noise in the field. The criteria for judging the accuracy is based on the uncertainty in the noise model input data following the approach outlined in European Commission WG-AEN (2006).

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. The key for that achievement is that the measurement locations were carefully chosen to be close to the container related activities as much as possible, and away from any non-container activities that are not included in the noise map simulation. The only exception is the slight inaccuracy in the spatial model in one of the location which resulted in higher simulated noise in the noise map. Consequently, the elevation model will need to be adjusted to account for the new elevation changes in the field.

3.3 Evaluation of noise impact using noise maps

The noise maps can be used to evaluate the noise impact on the residential area to the west of the port. It can be seen that the noise level for that area does not exceed 55dB during the day period. This 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 level in the residential neighborhood is 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 (Figures 29 and 30), cargo handling activities only (Figures 31 and 32), and train activities only (Figures 33). 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.

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.

So, overall, the noise level from the container related activities at the port are within the relevant noise guidelines and no excessive noise is observed.

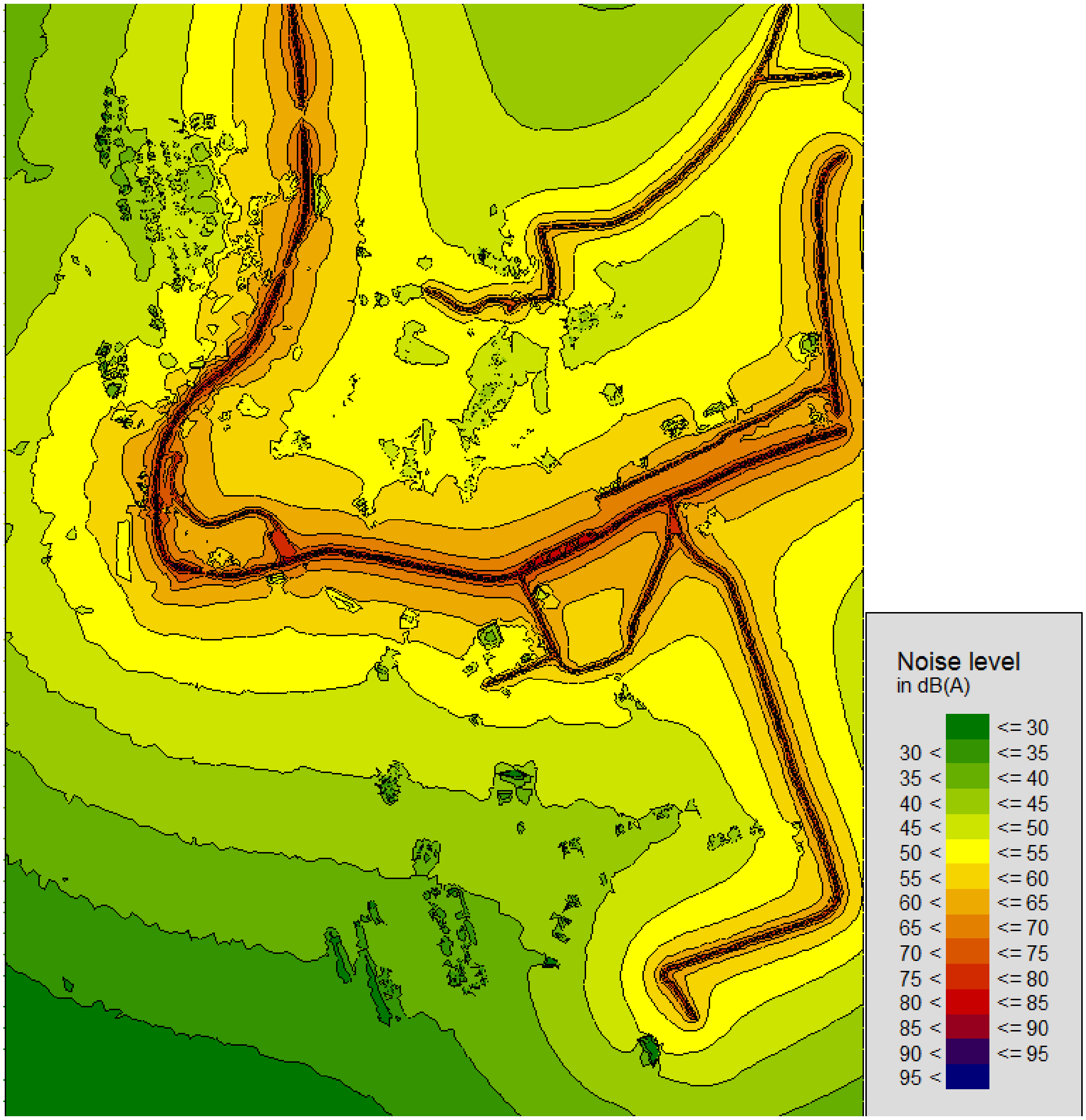


Figure 29. Noise map for day period (6am-10pm) with only truck traffic

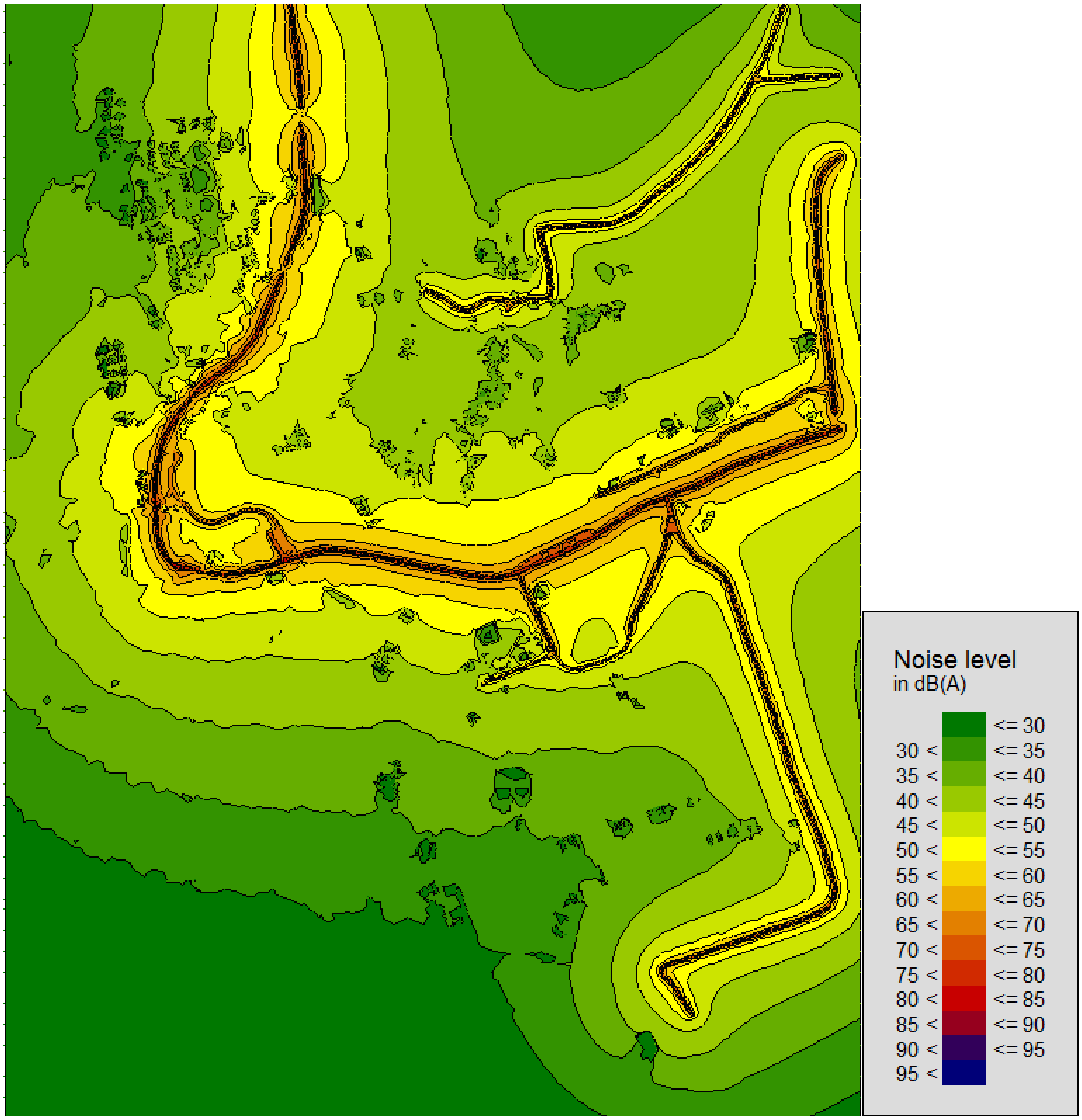


Figure 30. Noise map for night period (10pm-6am) with only truck traffic

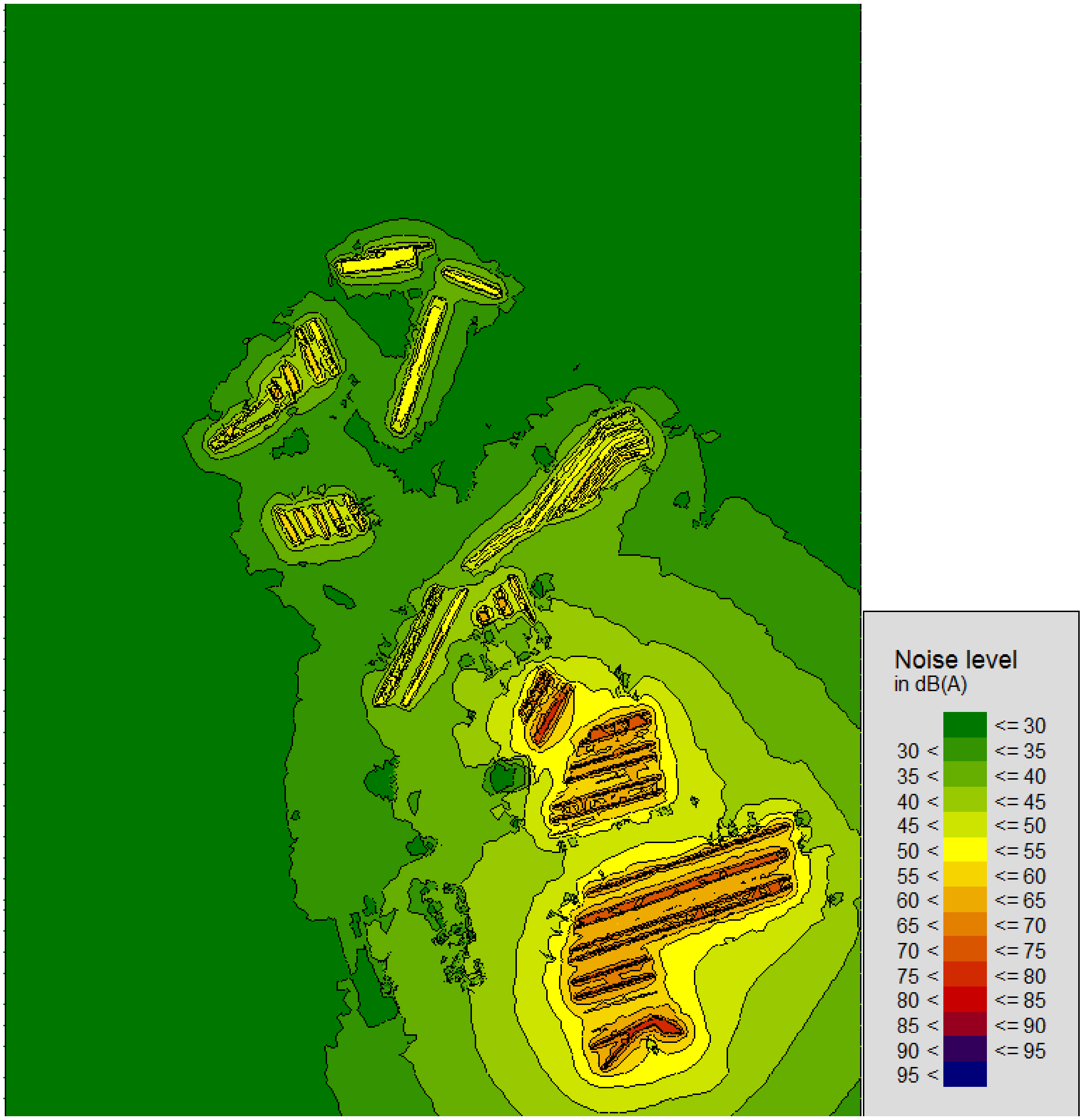


Figure 31. Noise map for day period (6am-10pm) with only cargo handling activities

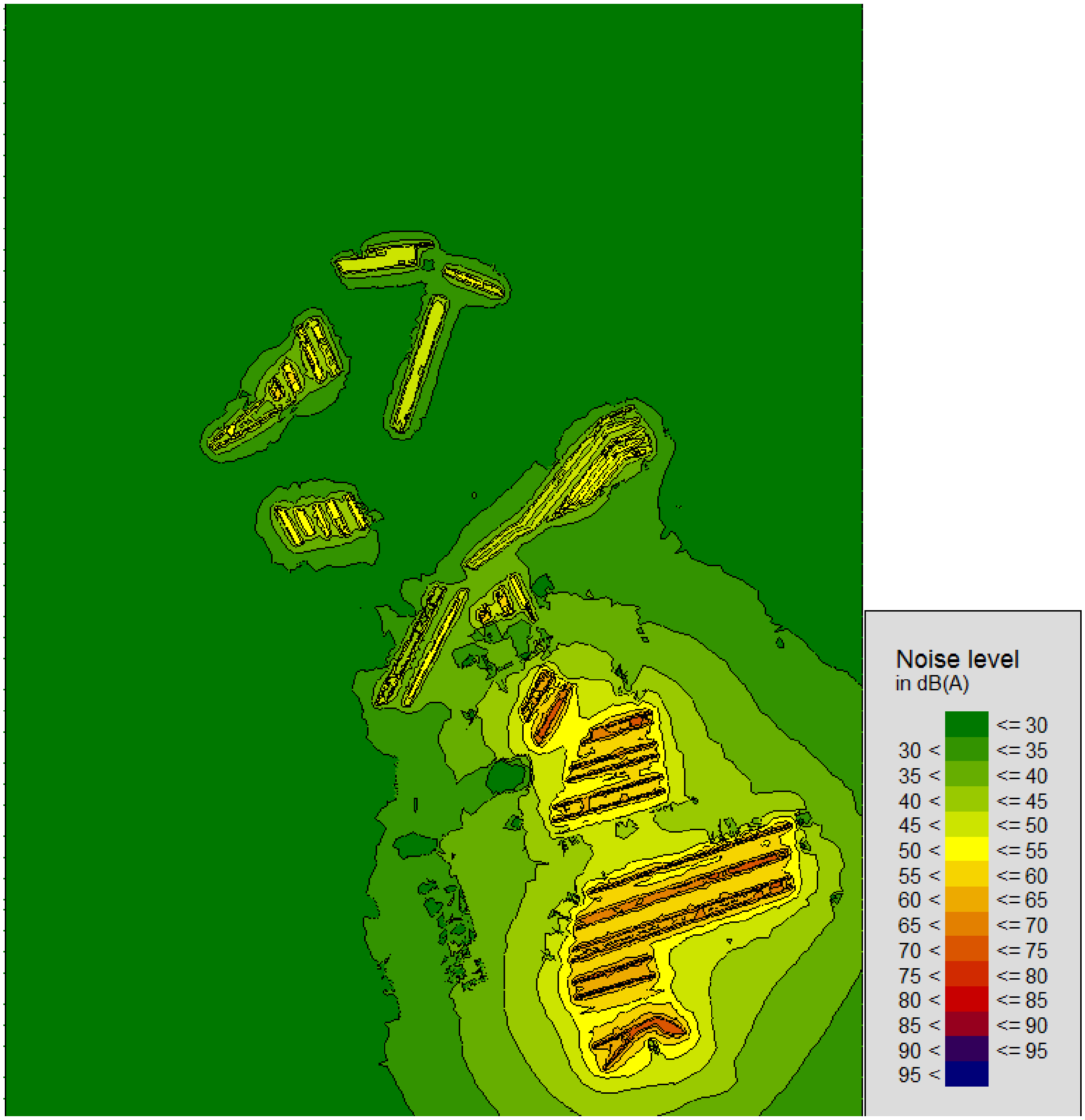


Figure 32. Noise map for night period (10pm-6am) with cargo handling activities

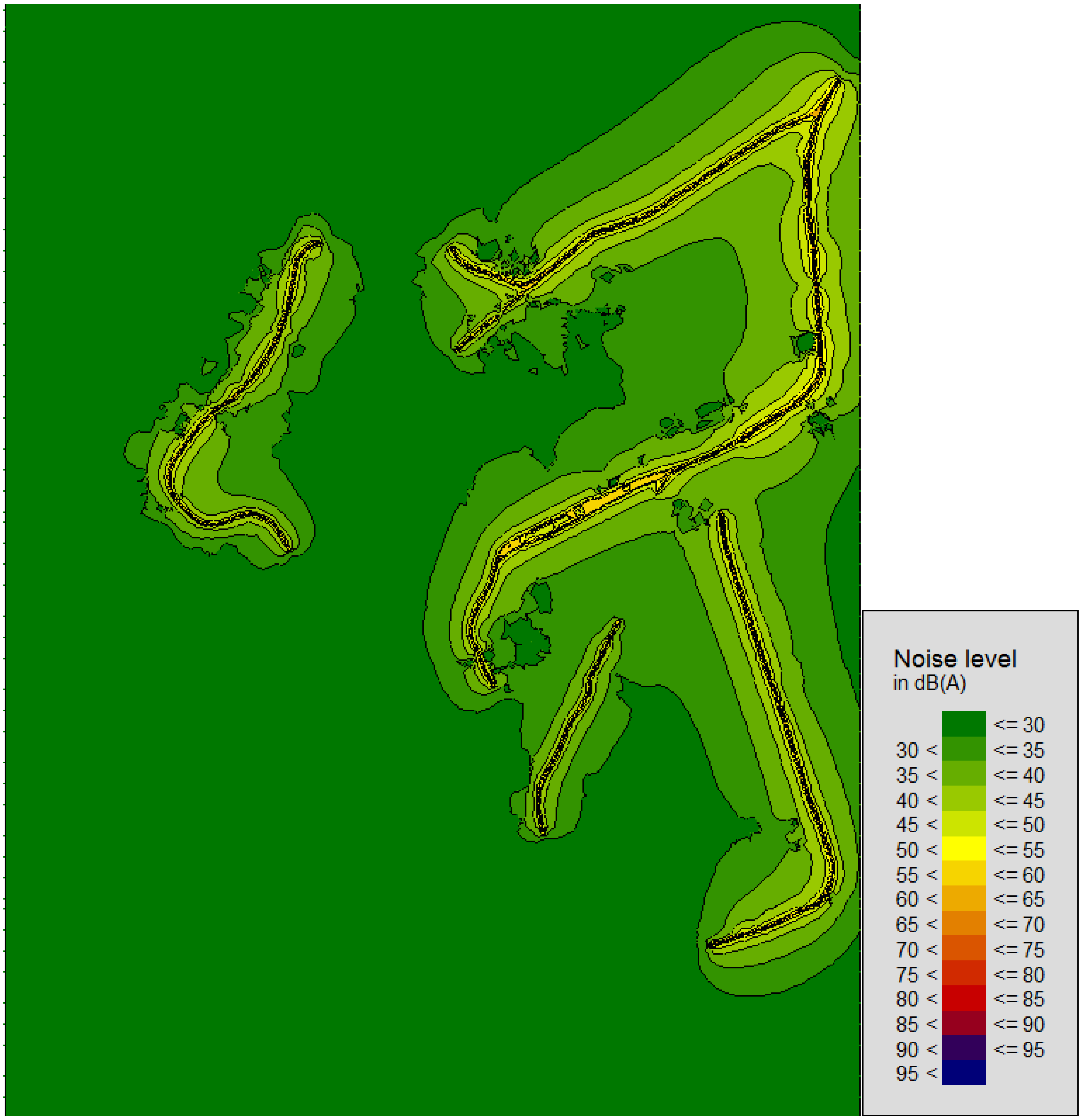


Figure 33. Noise map with only train activities

4.0. Research findings and discussions

This section will highlight some findings from the research project, which are organized as follows: first, the key findings from the project are pointed out; second, noise data analysis is discussed; next, several observations obtained the project are listed; finally, recommendations for preventing the noise impact at the Port are presented.

4.1 Key findings

The key findings with respect to different subjects were extracted from Figures 15 through 33 presented in the previous section and are summarized in the table below.

Table 9. Key findings

Subject	Key findings
Hourly noise	• The highest noise is at location 8 around 9am (76.9dB) and lowest noise is at location 3 around 1pm (65dB). Location 6 experienced the largest variation throughout the day (3.2dB), while location 8 has the smallest variation, 1.2dB. . For the locations near the truck entrances such as locations 3 and 5, there is a good correlation between the noise levels and the truck activities. • On average, 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 is consistent with the operating characteristics of the container terminals at the port.
Hourly truck activities	• Location 1 has the highest truck activity around 1pm (1182 trucks/hr). The same location has the next highest truck activity around 11am with 1176 trucks/hr around 1pm. • The lowest truck activity is around noon time (386 trucks/hr). The peak truck activity is around 2pm (699 trucks/hr).
Daily noise	• The average noise level has a slight peak on Friday (72.7 dB), but varies only by 1.1dB throughout the weekdays. The lowest noise is on Wednesday (71.6 dB). • The highest noise is found at Location 9 on Thursday (76.9 dB) and the lowest noise on a weekday is at location 3 on Monday (65.3 dB). Location 7 experienced the largest variation throughout the weekdays (3.7 dB), while Location 4 has the smallest variations, 1.2dB.
Daily truck activities	• The highest truck activity is on Wednesday (327 trucks/hr) and the lowest is on Monday (267 trucks/hr), for weekdays. • Location 1 on Wednesday has the highest truck activity (745 trucks/hr). The second highest one is Location 1 on Friday with 691 trucks/hr.

Monthly noise (July 2011 to July 2012)	• The noise peaks are in July through September (73.6-73.9 dB). The lowest noise is in December (70.7dB). • The highest noise is at Location 4 in September (78.4dB) and lowest noise is at location 3 in December (63.7dB). Location 5 experienced the largest variation throughout the months (7.6dB), while Location 1 has the smallest variation, (3.1dB).
Monthly truck activities	• The average truck activity is highest in July (353 trucks/hr) and lowest in September (188 trucks/hr). • The highest truck activity in June and July (721 and 746 trucks/hr).
Overall noise	• 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.
Overall truck activities	• Location 1 has the highest truck activity (538 trucks/hr), following by Location 4 (322 trucks/hr) and Location 5 (267 trucks/hr).

4.2 Data analysis

The generated noise map can be used to infer the noise data for an area of interest, which are then analyzed to come up with an appropriate action planning. In this study, the data analysis is aimed at identifying: (1) The most significant noise sources (both group and individual sources) and (2) The hot spots and high priority areas. For each of these aims, generic methodologies and relevant guidelines are presented below. Examples of good practices are highlighted where necessary.

Significant noise sources: are referred to as the sources from which most of the environmental noise levels are generated. The significant noise sources can be identified by two steps: First, the relative importance of groups of noise sources such as industry, port terminals operations, roads, railways and ship movements is defined and then the significance of single sources (e.g. a specific activity, specific road) is identified. In this study, the research team was trying to analyze the overall noise contribution and distribution in general, rather than focusing on any single source or location. Data obtained from the generated noise map revealed that the highest contribution of noise is from the truck activities. Also, the noise contribution from the railroad is found not significant. On further analysis, it was concluded that the noise level generated from the container truck traffic on the roads is within the allowable limit (i.e. 71 dB from the Caltrans/FHWA guidelines for developed land, 50 feet away from the roads).

Hot spots and high priority areas: are defined as a critical point where noise levels reach the maximum allowable limits and/or the effect of noise on sensible receptors is significant. In this study, the hot spots and high priority areas were identified if they met the following two conditions: (1) where noise levels reach their maximum allowable limits, and (2) where there are sensitive areas and significant noise levels are observed. Being located in a predominantly industrial area, the Port of Los Angeles has few sensitive areas in its immediate vicinity. From the noise map, the impact of noise on these two areas can be evaluated.

- The noise level for the residential area close to the Port does not exceed 55dB during the day period. This 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 level in the residential neighborhood is less than 50dB.
- The truck movement activity is the highest source of noise, while train activity contributes the least to the overall noise. Consequently, the noise levels are concentrated on the roads and they are within the maximum allowable limit (71 dB for developed land and 50 feet away from the major roads) in accordance to the Caltrans/FHWA Noise Abatement Criteria for Category C activities.

From the noise map, the peak average noise level of the different key noise sources (trucks, trains, cargo handling equipment) is summarized in Figure 34. The values were taken 50 feet from the noise source. It is obvious that trucks contributed the highest average noise level and trains generated the least.

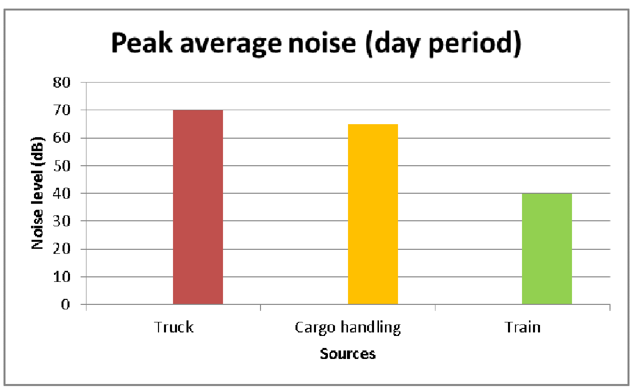


Figure 34. Peak average noise levels by noise source

4.3 Lessons learned from the study

This sub-section discusses several lessons learned from this study.

Data collection issue: This study on noise at the Port of Los Angeles provided several lessons for future research work: (i) The key of success in collecting data needed for the project is the support from and collaboration between all the involved parties, authorities, companies and agents; (ii) Before any data collection can be made, an overview of the input data requirements and availability must be done. Also, utilization designations for the different noise data sets should be clearly defined; (iii) Significant noise sources should be identified at an earlier instance so that unnecessary data collection can be avoided; and (iv) For data validation using noise measurements at typical locations, it is very important to select locations that are close to the activities of interest.

Data validation: The data of noise sources as well as operational activities at the port should be validated for their accuracy since inaccuracies of the data could lead to poor quality noise mapping, which in turn could negatively affect the value of action plans derived from their interpretation. The data validation can be done by either validating the input data sets or measuring noise levels in selected locations and then attempting a comparison between the predicted and the measured noise levels. While the second approach provides the comparison for assessing the accuracy of noise maps, it is unable to identify the causes of potential inaccuracies. The validation of the input data sets can help to find where the inaccuracy or error comes from. For this study, the research team was restricted to obtaining the noise characteristics and operational details of several noise sources. Therefore, the data validation for this project was done through selected measurements of the overall noise. In effect, the noise levels obtained from the generated noise map was compared with the actual noise levels measured on the field at selected locations throughout the Port. It is observed that the differences are within the acceptable range if the measurement locations are close to the activities of interest, and away from unrelated sources that are not included in the noise study.

4.4 Recommendations

Action plans for noise management: It is necessary that appropriate action plans for noise management should be developed before the negative noise impacts on the people and the environment in the Port can be avoided. After the action plans are developed, the noise management team should come up with a methodology of how to effectively implement the noise management program. Such a implementation should provide environmental quality of the port surroundings and improve the working environment by raising awareness of safety, health and environmental issues amongst employees. In addition, cost/benefit analysis should be an integrated part of the noise management program as it indicates the best solutions that should be implemented so that the best possible environmental performance can be achieved at the lowest possible costs.

Noise minimizing measures: The noise distribution can be minimized by means of source mitigating measures, propagation measures, or receiver measures.

- Source mitigating measures can reduce or eliminate noise directly at the source. Examples of source mitigating measures for port terminals are: Installing insulation materials to sound intensive components; using absorbing building materials; using silent equipment (low noise versions cost little extra); slowing the speed of putting down a container; using electricity instead of diesel or diesel-electric moving equipment; plating trees as a barrier.
- Propagation measures reduce the impact of noise during its path from source to receiver by means of physical barriers that attenuate or deflect the noise transmission. Another propagation measure is to optimize the infrastructure and terminal layout so that noise impacts can be eliminated or minimized. For

example, ships/berths should be located, if possible, away from the residential areas.

- Receiver measures, also known as passive measures, may be used in residential areas to prevent the inhabitants from noise pollution. These passive measures are adopted when the source and propagation measures are not acceptable. The installation of passive noise control measures is based on calculated or measured outside noise levels.

The port authorities can use the result of this study as a tool to predict future noise impact on new development plans of the port and its residential surroundings. For example, the noise model can be used to assess where new and future development will have the greatest negative impact. This will help the port authority to make appropriate decisions for the future developments.

5.0 Conclusions

This Section will summarize the noise problem at the Port of Los Angeles, the research results, and the usefulness of the research results for academic, professionals of the Port authority as well as policy makers of the California State.

The noise problem: As one of the largest ports by container volume and cargo value in the United States, the Port of Los Angeles is subject to high traffic numbers and many industrial activities. As a result, nearby residential areas may experience elevated ambient noise levels such that assessment of noise impacts and plans of noise management are certainly needed. Among the terminals at the Port of Los Angeles, the container sector has the highest growth potential. Consequently, the most significant sources of noise at the container terminals are the ships, straddle carriers, cranes, fork lifts, refrigerated containers, trucks and trains. The problem was the high noise levels generated from these sources may have a negative impact on the performance and health of the people working at the container terminals as well as the residential surrounding neighbors; however, there have never been any research work specifically conducted in regard to this problem at the Port. This study investigated noise pollution at the container terminals at the Port, which was then modeled in a computer software to obtain noise maps. These noise maps can be used by the port authorities to evaluate the existing noise conditions of the Port and predict future noise impact on new development plans of the Port and its residential surroundings.

The research results: The noise maps generated from this study present the noise distribution in and around the port areas. The noise maps also 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.

The usefulness of the research results: The results of this study indicate 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. In this study, the noise maps modeling the noise data for several areas around the Port indicate that overall, no excessive noise levels were found.

Appendix: Typical data worksheets

Location # 1

Month of	Truck	Average Leq noise
July	480.350	73.252
August	444.770	73.442
September	368.020	70.886
Octobor	497.500	73.171
November	547.787	71.454
December	466.008	70.648
January	556.875	71.271
Feburary	555.433	70.328
March	528.960	70.947
April	553.708	71.806
May	525.600	71.543
June	721.060	73.125
July	746.333	73.157
Average	537.877	71.925

Location # 3

Month of	Truck	Average Leq noise
July	180.450	64.540
August	171.960	66.256
September	176.727	67.369
Octobor	187.217	66.195
November	170.907	64.809
December	136.900	63.692
January	186.000	65.081
Feburary	153.467	65.107
March	149.560	64.416
April	200.958	66.240
May	205.133	65.853
June	232.180	67.218
July	219.600	66.445
Average	182.389	65.632

Location # 4

Month of	Truck	Average Leq noise
July	337.067	76.665
August	353.010	77.846
September	268.300	78.395
Octobor	290.717	75.904
November	333.760	72.591
December	316.900	72.515
January	380.375	73.781
Feburary	312.100	71.173
March	312.420	72.746
April	350.958	72.242
May	290.600	72.930
June	343.540	74.046
July	300.667	71.863
Average	322.339	74.054

Location # 5

Month of	Truck	Average Leq noise
July	323.100	75.965
August	289.470	75.731
September	245.393	75.977
Octobor	301.617	76.463
November	215.883	74.600
December	227.111	72.558
January	297.083	73.663
Feburary	238.867	73.667
March	208.700	73.018
April	201.458	69.671
May	296.800	68.960
June	292.440	70.291
July	328.867	68.867
Average	266.676	73.033

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