EVALUATION OF URBAN TRAFFIC NOISE POLLUTION AND ITS REMEDIAL MEASURE : A CASE STUDY

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Abstract— Noise is a prominent feature of the environment including that from sources such as transport, industry and neighborhood. Noise pollution is becoming more and more acute, and hence many researchers are studying the effect of noise pollution on people and its attenuation. In this thesis an attempt has been made to find the measures for the reduction in noise levels. Different sources have been identified that have potential for generation of noise pollution. Sources which are identified for the study are: noise level generated from vehicular traffic, noise from flour mill operation, construction machinery, and so on so forth.

Currently, noise pollution is a major problem especially in urban areas, and moreover traffic noise is the most significant source of noise in cities. A large number of cars and other road vehicles that have internal combustion engines are making road traffic noise a leading noise pollution source. Electric and hybrid cars, which are nowadays slowly replacing them, give rise to lower noise level in urban areas as their engines are generally silent. However, the mere absence of internal combustion engines cannot be the only measure for lowering noise levels in urban areas. The goal of this chapter is to define and describe traffic noise, the reasons for its occurrence, and all existing ways of reducing traffic noise.

Research involved in field measurement of the noise levels generated by a traffic flow in an open stream as well as on a road provided with noise barrier. The noise that is generated from the existing system of operation is about 6% to 58% higher than the standards prescribed by the authorities. Such a severe noise pollution has to be reduced. Hence effective noise barrier was devised to attenuate the noise and the outputs are presented in the form of numerical results.

1. INTRODUCTION

Sound that is unwanted or disrupts one's quality of life is called as noise. When there is a lot of noise in the environment beyond certain limit, it is termed as noise pollution. Sound becomes undesirable when it disturbs the normal activities such as working, sleeping, and during conversations. It is an underrated environmental problem because of the fact that it can't be seen, smelt, or tasted. World Health Organization (Report 2001) stated that "Noise must be recognized as a major threat to human well- being"

Noise is normally defined as 'unwanted sound'. A more precise definition could be: noise is audible sound that causes disturbance, impairment or health damage. The terms 'noise' and 'sound' are often synonymously used when purely acoustical dimension is meant (e.g., noise level, noise indicator, noise regulation, noise limit, noise standard, noise action plan, aircraft noise, road traffic noise, occupational noise, etc.). The link between exposure and outcome (other terms: endpoint, reaction, response) is given by reasonably well-established exposure-response. Managing noise is crucial for enhancing the living condition of a dwelling. Noise can be generated internally within a building (e.g., noise from surrounding neighbors' voices, music or appliances) or externally (e.g., traffic noise from automobiles, buses, trains, aircraft, industrial activities or surrounding construction activities). Noises (or impact of sounds) are transmitted through building materials from sound sources such as vehicular or foot traffic, banging, or objects being dropped to the floor and can also be associated with vibrations. The design solutions for limiting air-borne and structure-borne noises are not always the same as stated by Li et al (2000).

Nowadays noise pollution is the focus of various studies and research due to its proven significant impact on human health and work efficiency. Research shows that traffic noise in urban areas has tremendously increased since the beginning of the century, primarily due to increased transportation of people and goods. It can be concluded that in urban areas the largest source of noise is traffic-induced noise, which accounts for 80% of all communal noise sources. Traffic noise caused by road traffic is the most common type of noise in urban areas and as such poses a serious problem. Figure 1 shows the distribution of human noise annoyance according to the type of noise source [1].

According to Table 1, provided by the International Union of Railways (UIC), all types of trains produce less noise than trucks, cars, airplanes, and other means of transport. Railway is the most favorable form of transport, in terms of noise as an influential factor for environmental degradation and human health. Therefore, it can be determined that the railway has the lowest share of noise in urban areas among other means of transport.

Noise is an environmental problem which poses various negative effects on health and economy, and has increasingly attracted the attentions of researchers and engineers in recent years. Studies show that 30% of European Union (EU) citizens are exposed to traffic noise exceeding the acceptable level recommended by the World Health Organization (WHO), with 10% complaining of sleep disturbance at night (Ahammed, 2009). Environmental noise causes various negative effects on human beings, such as cardiovascular effects, blood pressure rising, stress and vasoconstriction increasing, and increasing risk of coronary artery diseases. In Denmark, about 800 to 2,200 people are admitted to hospitals annually with high blood pressure or heart disease and 200 to 500 die prematurely which are considered to be associated with high levels of traffic noise (FEHRL 2006).

The tire/pavement interaction noise has been proven to be the major source of the traffic noise, especially for cruising driving conditions (Sandberg and Ejsmont, 2002). The research proposed by de Graaff and van Blokland (1997) indicated that about 90% of the equivalent sound energy in urban traffic is generated by tire/pavement interaction. Consequently, reduction of tire/road noise can be an efficient way for traffic noise mitigation. Road re-pavement has been a method applied for traffic noise reduction. The noise reduction mechanisms by the pavement itself include acoustic and mechanical impedance, in which the acoustic impedance depends on the surface characteristics (i.e. porous or non-porous), and the mechanical impedance is related to the relative stiffness of the tire and pavement (Neithalath et al., 2005; Ahammed, 2009). It has been demonstrated that decreasing pavement stiffness decreases the noise generated on the pavement. However, as time passes, the relative stiffness of the pavement would change due to various conditions. The chemical effects of the weather, assisted by road salt, create a weathering and crumbling surface which affects both micro texture and macro texture of the pavement, leading to variations in relative stiffness and surface characteristics. Consequently, it is required to investigate the effect of operation time of pavement on traffic noise emission, and further explore the interactive effects of operatioin time of pavment and other impact factors (e.g. traffic flow, traffic composition) on traffic noise pressure.

2. LITERATURE SURVEY

In noise studies, several types of weighting networks are performed on sound spectra to calculate the equivalent sound level for different objectives. At low noise levels, the "A" weighting networks have been proven to correlate well with the sensitivity of human hearing and widely accepted as the sound level parameter in noise studies (Dai et al., 2008). Tire-pavement or traffic noise is rated as moderate sound, and thus it is usually measured as "A" weighted equivalent continuous sound level (Sandberg and Ejsmont 2002, Bruel and Kjaer 2007; Ahammed, 2009). In the present study, the equivalent traffic noise levels and the corresponding requirements are collected in the form of "A" weighted equivalent continuous sound level (LAeq).

In order to explore the noise reduction effect of pavement, reliable acoustical measurements are necessary for tire and pavement with respect to traffic noise emission. Several methods have been developed for measuring the tire/pavement noise in recent years. According to the test location, the noise measurement methods can be classified into three groups: roadside measurements, on-board measurements and laboratory based measurements (Lou, 2007). In detail, the roadside measurements include the Statistical Passby, Controlled Passby, and Time-averaged Traffic Noise methods.

The Statistical Passby method utilizes a random sample of typical vehicles measured one at a time, in which the maximum sound pressure level is captured for each passby through a sound measurement system located either 7.5 m or 50 ft from the center line of the traffic lane (Bernhard and Wayson, 2005). The SPB method can be employed to account for all aspects of traffic noise, including noise emitted by engine, exhaust and aerodynamic mechanisms, at the sideline of the test road section, as well as take into account the variation that occurs across vehicles of the same type (Bernhard and Wayson, 2005; Lou, 2007). This method is widely applied to study the influence of pavement conditions on environmental noise.

The measurement steps for the controlled passby (CPB) method are the same as those of the SPB method, in which the maximum sound power of each vehicle would be collected. The difference between the two methods is that the speeds of test vehicles are controlled in the CPB method (Lou, 2007). The CPB method takes less time than the SPB method, but it cannot account for the variation that might occur in vehicles of the same type (Bernhard and Wayson, 2005). Furthermore, both the SPB and CPB methods require a light traffic density and thus they are more suitable for rural traffic conditions.

Time-averaged traffic noise measurements are developed to test heavy traffic density conditions in which vehicle passbys are not sufficiently isolated. For time-averaged measurements, sound pressure is averaged and converted to the equivalent noise level or Leq (Bernhard and Wayson, 2005). The value of Leq represents the equivalent continuous noise level throughout the elapsed time. For time-averaged methods, the traffic composition, traffic flow, speed and meteorological conditions are not controlled so a normalization process based upon traffic noise models is used to develop a comparable long-term equivalent noise descriptor of noise at the test location (Lou, 2007). Usually, the time-averaged methods are suitable to the site with the background noise at least 10 dBA lower than the traffic noise, and the noise level is calculated according to the noise indicators recommended by the ISO Standard 1996/1 Acoustics – "Description and measurement of environmental noise".

3. CONCEPTUAL FRAMEWORK FOR PPP PROJECTS

Road traffic noise depends on the following three factors:

- Type of road vehicles.
- Noise Pollution
- Friction between the vehicle wheels and the road surface.
- Driving style and driver behavior.

When considering vehicles that have an internal combustion engine (ICE) as the noise source, most of the noise comes from the sources or systems shown in Figure 2. The aforementioned sources and systems are explained in detail in the following paragraph.

Engine noise is created during the process of compression and expansion in the engine, which creates engine vibrations which then emit noise. The engine noise depends on the engine volume, speed, and capacity. The suction system noise is caused by the opening and closing of the suction valves, and furthermore the intensity of such noise depends on the mode of operation of the engine, the speed of the engine itself, and the type of air filter. Noise from the exhaust system is created by the sudden release of gas into the exhaust system itself in order to open the exhaust valve. The fan noise is generated due to the operation of the fans in the vehicle, and the fans generally produce a broadband noise.

The pollution of environmental noise in urban areas has increasingly attracted the attentions of researchers and engineers. Environmental noise causes various negative effects on human beings, such as cardiovascular effects , a rise in blood pressure, an increase in stress and vasoconstriction, and an increased risk of coronary artery diseases.

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In terms of noise pollution, electric vehicles represent the future, especially when compared to vehicles with an internal combustion engine (see Figure 3). However, at low speeds, electric vehicles produce very small levels of noise, i.e., in current acoustic urban environments, they are practically inaudible. For example, the noise level difference between an electric vehicle and an internal combustion

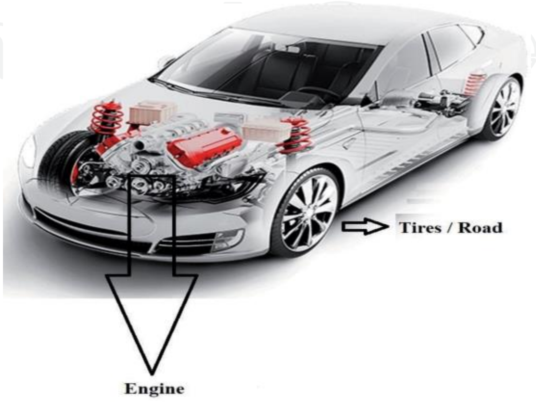

Figure 3.1 Noise sources in a vehicle.

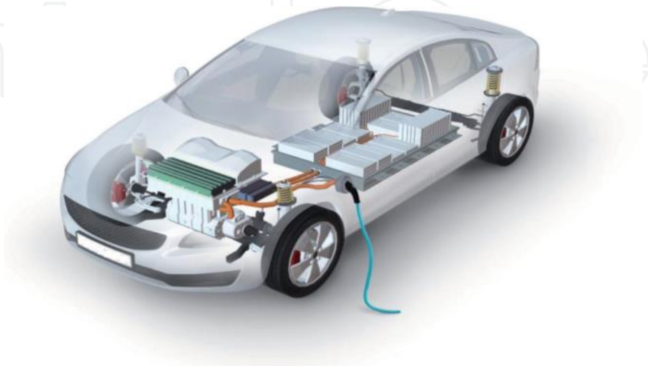

Figure 3.2 Electric vehicle.

engine (ICE) vehicle can be greater than 6 dB (A) at 10 km/h. Unfortunately, much later at higher speeds, both types of car become equally loud, mainly due to tire noise.

When considering how traffic flow affects the subjective perception of noise levels, it can be concluded that it depends on the number of vehicles, their speed, and structure as described in the following paragraph.

A traffic flow of 2000 vehicles per hour produces twice the perceived noise level than 200 vehicles per hour. If the traffic speed is 105 km/h, it produces twice the perceived noise level than the 50 km/h traffic flow. One heavy weight vehicle (HV > 3.5 tons) with a speed of 70 km/h creates a perceived noise level of 28 light- weight vehicles (LV <3.5 tons).

4. TRAFFIC NOISE REMEDIAL MEASURES

- Urban planning.
- Designing living spaces.
- Sound insulation of living spaces.
- Smart traffic management.
- Implementation of quiet road surfaces.
- Development of train brake blocks.
- Electric cars.
- Changing driving styles.
- Noise barriers.
- Application of soundscape concept.

It is important to emphasize that these solutions are not the only solutions and that there are still different opportunities and prospects for progress and develop- ment of both existing and new methods.

In the following sections, a more detailed explanation on how electric vehicles affect the reduction of noise levels will be provided, especially in urban areas. On the other hand, problems which occur with electric cars will be discussed. In addi- tion, the effect of smart traffic management system, traffic behavior changes, and quiet road surfaces in terms of noise reduction will be examined.

A. Electric vehicles

Electric vehicles (shown in Figure) present the future in terms of reducing noise pollution in urban areas. Electric vehicles are quieter especially when com- pared to vehicles with an internal combustion engine.

Electric vehicles at low speeds produce very low levels of noise, i.e., in current urban environments, these vehicles are practically silent and unnoticeable. For example, the difference in noise level between an electric vehicle and an internal combustion engine vehicle can be greater than 6 dBA at 10 km/h [6]. At higher speeds, both types of vehicles become equally loud, mainly due to the tire noise. In urban areas, for pedestrians (especially for vulnerable groups: children and visually impaired people), it becomes much more difficult to detect electric vehicles due to their aforementioned lower noise levels [6]. Therefore, it is necessary to find a solution in the form of an audible signal that electric vehicles will emit in different driving modes.

Since 2009, the Japanese government, the United States Congress, and the European Commission have been studying the legislation to determine the mini- mum level of emitted sound signal for plug-in electric and hybrid vehicles when operating in electric mode. This level of audible signal must be such that visually impaired people, other pedestrians, and cyclists can hear the electric vehicles in motion and detect from which direction they are coming from. Several tests and studies have shown that vehicles operating in electric mode below 32 km/h are almost inaudible for pedestrians [7].

For example, a case study was carried out in Zagreb in 2019 [11], which involved 201 participants who had the task to fulfill a specially designed questionnaire. This case study addresses the issue of electric cars in everyday traffic. The research was focused on assigning a desirable (both for pedestrians and drivers) and, at the same time, detectable warning sound to an electrical vehicle in the daily traffic. The case study showed that the majority of participants (especially the ones with a driving license) would prefer that their electric vehicle sounds like an internal combustion engine car. The “nondrivers” were more open to the solution that an electric vehicle has a different sound than a “regular” car. According to the study, they were more opened to a solution of adding a sound of an electric motor to the electric vehicle as a warning sound which would distinguish the electric cars from cars with internal combustion engine in everyday traffic. However, an important question concerning the overall quality of life remains: “Which one of these two sounds would increase more the noise levels in urban environments?”

Finally, it can be concluded that electric vehicles will play a significant role in reducing noise levels especially in urban areas while adequately addressing the problem of emitting a certain warning sound when parking, moving forward, and stopping. It is important to note that the unique warning sound has not yet been implemented, i.e., various car manufacturers are still “experimenting” regarding this issue.

B. Smart traffic management

Smart traffic management is a system in which centrally controlled traffic signals and sensors regulate the flow of traffic through the city in compliance with the current state on the roads in the city (see Figure 14).

Upgrading and integrating all the signals on major roads in the city will have multiple benefits such as:

- Significant reduction of daily traffic congestion, equalization of traffic flows, and prioritization of traffic in response to real-time demand.
- Pollution reduction in the city: stop-start driving is inefficient and polluting.
- Providing priority for busses approaching intersections and phase-coordinating traffic lights enabling a “green wave” through the city.

Figure 4.1. Smart traffic management system.

Enabling a much more efficient response to traffic accidents, especially on motorways, for example, the system can be pre-programmed for a sudden increase in traffic.

C. Enabling inbound traffic flow control.

In addition to the multiple benefits listed above, the system would also provide the perfect opportunity to install tracking equipment and collect a much more detailed traffic and travel data. Each set of traffic lights would have communication equip- ment that can be used to transmit (anonymously) vehicle data, either from automatic number-plate recognition (ANPR) cameras or Bluetooth detectors and closed-circuit television (CCTV) transmission (if suitable). There are three components in smart traffic management: traffic lights, queue detectors (in terms of traffic congestion) embedded in the road, and cameras and a central control system. Queue detectors define the traffic flow control system on all major roads in the city. The system controls the traffic lights to maintain the free flow of traffic within the city. Every 2 seconds, the system uses a real condition model to decide whether one will have the priority of changing the phase of any of the traffic lights. A system software con- sidered as an “asset” can be defined as, for example, obeying the bus timetable, less pollution at a particular location, or fewer vehicles waiting at a highway toll booth.

If inbound traffic flow control is used, the most remote sets of traffic lights on arterial or radial roads serve as a special function and are technically known as “doors” or “control points.” They regulate the flow of vehicles entering the city.

One example of software with the purpose of smart traffic management is split cycle and offset optimization technique (SCOOT) which is used in hundreds of European cities for decades. It is used in Cambridge for coordinating traffic signals, where it usually favors busses. In Zurich, Braunschweig, and Potsdam, the system is used to control all traffic in the city [12]. The software is deployed with “knowledge” of the road network and is trained to respond appropriately to a wide range of scenarios (e.g., major traffic “disruptions” such as an accident on the arterial roads). It is important to note that the system also has the option to manually manage and make changes if there is a need for it.

D. Changing driving styles

Traffic behavior psychology is defined as the study of the behavior and psycho- logical processes of different traffic participants. Its aim is to attempt to identify specific behavior patterns of users of different types of traffic with the ultimate goal of developing effective anti-accident measures [13]. There are two basic approaches that can help psychologists develop and implement measures against traffic acci- dents. First, traffic psychology can act as an “assistant” of science with a dominant field of traffic engineering. Road safety engineering solutions aim to optimize internal road safety. A safe road can be defined as a road that is designed, operated, or modified in such a way that it [14]:

- Warns the driver of any unusual or odd features.
- Informs the driver of road conditions.
- Guides the driver through atypical parts.
- Controls the passage of drivers through problematic points and roads (“black” traffic points).
- Has the ability to tolerate a driver’s impolite or inappropriate behavior.
- Engineering is powerful for a significant number of traffic problems. However, it would be wrong to assume that it is exclusively an engineering solution.

5. CONCLUSION

Noise pollution is a serious problem that affects the overall quality of life. This problem is especially noticeable in urban areas where a significant amount of noise pollution is produced by traffic. In this chapter the main traffic sources are described and analyzed. In addition to road, railway, and aircraft noise sources, other typical noise sources common for urban areas are also discussed. Bearing in mind the serious consequences of long-term exposure to noise, it is necessary to implement at least some measure to reduce noise levels. Today there are many initiatives and plans how to tackle this issue; however this chapter has focused on measures directly connected to traffic noise levels. In that sense, this type of noise reduction measures has been described and discussed in detail.

Furthermore, it can be concluded that education and some form of encourage- ment are needed to get the people more involved in the “fight” against noise and its negative impact. In this way, a kind of pressure would be created to set up the necessary city infrastructure (sensor networks), and finally the citizens would obtain a much-needed improvement of the quality of life in the environments in which they live.

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