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Recent Engineering Applications for Noise Reduction in an Automotive Industry

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Research Article

Abstract − Industrialization harms as it results in the emission of noise into the surroundings and employees. Especially noise is one of the most common causes of hearing disorders and one of the most common occupational diseases in the industry. Reducing the main noise sources has become increasingly urgent since the effect on employee health was negative. Although noise reduction is an important issue in the industry, previous research has not addressed it adequately, particularly in the automotive industry. This paper presented a detailed case study on the reduction of noise in a pilot area of an automotive assembly line. The paper aimed to improve the quality of the working environment by reducing the use of Personal Protective Equipment (PPE) and noise reduction. For this purpose, noise measure tools were used: a Svantec-type noise dosimeter and a sound level meter. In the course of studies, it was creating noise maps (before/after), in order to verify whether the proposed measures will be sufficient. Once the proposed measures have been implemented, a 14.2% reduction in noise levels helped ensure employees' safety by reducing the need for mandatory PPE. Meanwhile, the noise reduction percentage for AGV is the highest among the five noise sources, at 20.9%. Results showed that the sound pressure levels dropped from 110 dBA to 87 dBA and reduced on average for AGV. Reducing reliance on PPE and implementing noise reduction measures enhances pilot area safety and contributes to a more ergonomic and sustainable work environment. The implementation of this case, the application of the suggested measures, and the subsequent verification approved a considerable reduction in the noise levels in the influenced pilot area, and the measures applied were assessed as highly effective with result rates.

Keywords − *Noise mapping, noise reduction, noise sources, sound pressure level*

1. Introduction

As a result of technological development and globalization, a significant point related to the hazards of employees comes to the forefront, namely, noise. Noise is among the most frequently occurring worldwide occupational threats, especially in the industry [1]. Various studies have reported that noise exposure can lead to hearing loss, sleep disturbances, psychological disorders, coronary heart disease, hypertension, and stress [2]. Nowadays, a widely used concept for preventing these diseases and improving life standards is to reduce industrial noise, above all in the industrial [3].

The industrial noise problem was explained as the industrial noise generated by industrials, and then how to consider the additional effect of other types of noise from the machine and equipment activities in the area [4]. Noise reduction has become an important part of the production process for all industries. Nowadays, especially in the production industry, with the increase in overall noise, the noise inside the production line is more and more related to equipment or technical machines. Noise-induced hearing loss is a prevalent form of industrial disease [5]. Therefore, reducing PPE use when sound levels fall below a certain threshold is

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necessary. In this context, conducting a comprehensive case study is required to minimize the impact of industrial noise on employees [6].

Although noise reduction is an important issue in the automotive industry, previous research has not addressed it adequately. This study aimed to improve the quality of the working environment by reducing the use of PPE and noise reduction. This gap in this field is not well-covered by existing case studies. That can be said to be the originality of this study. In this context, the paper presents the original research of the researchers, which is expected to contribute to the literature on noise reduction in the automotive industry.

This case study employs a unique approach to contributing to the automotive industry and literature. Conducted in a functioning production facility, the study fills a gap in the existing literature. The research results may aid in reducing noise and promoting Personal Protective Equipment (PPE) usage in industries. This paper describes the noise sources and presents the main noise issues. The conducted investigations are detailed, and the results are shared with all involved parties. Furthermore, the noise reduction strategies outlined in this study may serve as a guide for future research.

2. Literature Review

One of the troubles effects of industrialization is noise spreads into the surrounding environment. Therefore, with the increase in industrial manufacturing, more and more employees are exposed to the negative impacts of noise. According to recent studies, research aimed at reducing noise pollution is often linked to various health issues. However, there are only a few works that address both noise reduction and its related health outcomes. Table 1 provides details of some of the most noteworthy research studies in this area, along with their significant findings.

Table 1. Literature review

Authors	Focus of Interest	Methods	Findings
Deryabin [7]	In the automotive industry, it helps to partially improve sound insulation in the car interior.	Simulation	The method to reduce noise implies using acoustic plugs in the car interior.
Akmal and Bharathiraja [8]	A new design of the automotive engine mount for noise reduction	Simulation	The results showed that noise reduction of the engine mount was suppressed by approximately 14% to 26%.
Bennouna et al. [9]	The France automotive supplier aims to provide quiescence inside the car cabin by reducing Climate System noises during its operation.	Experimental investigations	The results for the considered climate systems induce a significant noise reduction on both structure radiation and aeraulic paths.
Mahadhir et al. [10]	Automotive muffler manufacturer in Malaysia	Experimental investigations (simulation)	The most suitable model for reducing the tailpipe noises is the model, which manages to reduce the noise by 3.07%, reduce the perforates number and shorten the length.
Qiu and He [6]	Noise reduction in a cigarette factory (The case of China)	Case study	Findings indicated that the average sound pressure levels were reduced by 6.5 dB(A).
Chang et al. [11]	They recruited 948 male workers in an aircraft manufacturing company in Taiwan.	Surveys	Findings indicate that noise-induced hearing loss may be related to the risk of hypertension.
Gan et al. [12]	This study included 6,307 participants of the USA National Health and Nutrition Examination Survey.	Surveys	Continually exposure to occupational noise is strongly associated with widespread coronary heart disease and hypertension, especially for young male current smokers.
Nawaz and Hasnain [13]	389 samples in the Pakistani population.	Surveys	Findings indicate that noise-induced hearing loss may be related to the risk of hypertension.
Van Kempen et al. [14]	A meta-analysis of 43 epidemiologic studies published 1970 - 1999.	Meta-analysis in literature	They present noise exposure hypertension and heart illness, which is consistent with an increase in cardiovascular disease risk in populations exposed to environmental noise.

Previous research has been conducted to explore relevant studies that analyzed noise reduction. Most researchers focus on changing worker behavior rather than noise. However, the case study could be rare, even though studies address the issue of noise reduction in the automotive industry, especially. This study aimed to improve the quality of the working environment by reducing the use of PPE and addressing noise reduction. Above all, the scarcity of case studies in the literature highlights a gap in this field.

3. Materials and Methods

The study was conducted as a case study in the organization known as ABC, which operates in the automotive field in Turkey on a large scale. The measurements were carried out during the production in June 2023, within the routine workflow of the facilities, which employ 2,000 personnel and are built on a closed area of 152,000 m² and an open area of 696,000 m². This case study analyzed the improvement steps taken based on actual data identified and eliminated the dominant noise sources by a team. The team building utilized managers, engineers, and a researcher in the present case study. The research data was collected from the assembly line, chosen as a pilot area. In ABC firm, 1 of 6 production lines called assembly line was observed.

Based on the sound pressure level measurement, the Svantec type 140 (SVAN 140) noise dosimeter with the Svantec type 971 (SVAN 971) sound level meter was used. The SVAN 104 is a noise dosimeter that meets the specifications for measuring workplace noise levels and hearing protection by health and safety regulations. The device measures noise dose and noise levels in the large-scale measurement range of 55 dBA to 140 dBA [15]. SVAN 971 sound level meter is a tremendous precision with options for octave analysis. The SVAN 971 is the best choice for many applications, including industrial, environmental, and general noise measurements. Another feature of SVAN 971 is providing data about the level of vibration that influences the measurement results [16].

The paper outlines the case study stages: determining the current status, taking measures, data collection, data analysis, and reporting.

(a) The initial stage of the whole process is to comprehend the current status of the noise conditions in the chosen operation, a significant part of which is the measurement of severe noise sources. The creation of current noise mapping aimed to visualize the process, determine an actual noise measure for the current assembly line, and consider the production effect. Noise maps are created to acquire data for studying noise reduction, and noise mapping illustrates the best way to identify noise sources [17].

(b) In the second step of mapping, all noise sources defined as point sources, with various types of noises disturbing the production workers were determined, which reduced concentration and productivity. The noise decibel (dBA) in the assembly line has increased in recent years due to the usage of more equipment with PPE warning sounds in the ABC firm. Therefore, one of the aims of this study was to reduce the use of PPE materials. According to noise-related regulations, the commonly confirmed standard to diminish hearing risk relies on exposure to 85 dBA for a maximum limit of eight hours per day, followed by at least ten hours of healing time at 70 dBA or lower (URL 1) [18]. Thus, reducing the impact of industrial noise on people requires a comprehensive study of noise sources and their mitigation strategies.

(c) In this context, the analysis of the noise levels to account for noise exposure time was determined in the third step. According to the Occupational Safety and Health Administration (OSHA) [19], permissible noise exposure time is provided in Table 2.

Table 2. Permissible noise exposure time [19]

Per day noise exposure time (hours)	Sound level slow response (dBA)
8	90
6	92
4	95
3	97
2	100
1½	102
1	105
½	110
¼ or less	115

Based on the information presented in this table, it appears that an employee has been exposed to certain levels of noise for particular durations: 110 dBA 1⁄4 hour, 100 dBA 1⁄2 hour, 90 dBA 1½ hours, etc. Since the exposure time value is within allowable limits, the exposure is within permissible limits.

(d) The next step generated an analysis of noise sources, noise pressure levels, and solution proposals based on the research team's data. Based on these measurements, dominant noise sources were recognized in the plant. With thorough information-gathering, team suggestions and measurements were taken to reduce the noise from sources, thereby reducing the negative impact on workers in the surroundings.

(e) Finally, in the fifth step, the implementation of the proposed measures, noise measurements were again performed in the area of the ABC plant. The noise measurements from various sources were conducted at 1 foot (30.48 centimeters) to ensure a comprehensive case. Specifically, measurements were taken 15 times, and distances between the noise source and the measuring device were maintained at 1 foot. The proposed measures were implemented thoroughly by the team proposal. The proposed noise measures were compared to both current and new conditions. It is evident from the noise measurements that there has been a substantial decrease in noise in the region following the implementation of the measures.

4. Results and Discussion

The team identified a pilot area on the assembly line with a current noise map, measured using SVAN 140 and 971. The noise level (dBA) in the assembly line has recently increased due to more equipment with relevant warning sounds for Occupational Safety and Health (OSH). Therefore, the assembly line was chosen as the pilot region. The model for the given dimensions of the assembly line was created using AutoCAD software, as shown in Figure 1, and exported to reflect the current status.

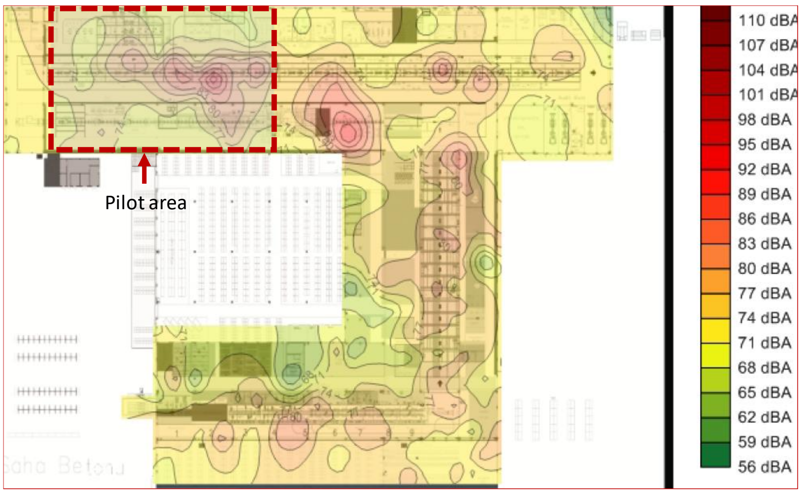


Figure 1. The current status pilot area

Figure 1 shows that the ‘noise from the pilot area’ is evaluated as a loud sound by almost all the devices compared to other assembly lines because of the loud sound of their operation. In the next phase of the case study, to gain knowledge of the current noise situation in the sources, noise measurements were carried out in the pilot area. While measuring this, noise exposure measurement devices (SVAN 140 and SVAN 971) were attached to the employees, and measurements were made in accordance with TS EN ISO 9612 - Measurement and evaluation of noise exposure in an acoustic working environment. The type of noise sources in Table 3 indicates significant sound impact, as determined by measuring devices and the measured results.

Table 3. Noise sources’ sound level

Type of Noise Source for Pilot Area	Sound Level (dBA)
AGV (Automated Guided Vehicle)	110
Motor crane	105
Pneumatic nut runner	95
Concrete slabs	94
Internal logistic	85

4.1. AGV

In the pilot area, noise intensity was measured on AGVs. Figure 2 shows the results before and after installing sound-absorbing materials on the fans of AGVs.

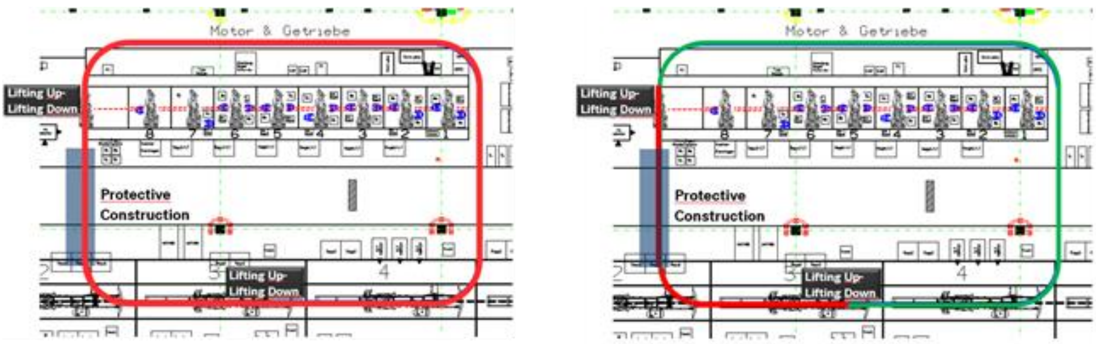
(Before) (After)

Figure 2. Elimination of noise fans of AGVs

The team recommended the installation of yellow stoppers on the AGV fans. Installing a sound-absorbing yellow stopper has reduced sound pressure levels by 110 to 87 dBA. As a result, it can reduce the noise intensity by 20.9%.

4.2. Motor Crane

Illustrate Figure 3, based on the noise measurements in the motor crane, which was broadband and evenly distributed, peaking at 105 dBA.



(Before) (After)

Figure 3. Reduction of crane buzzer noise level

After reducing the crane buzzer noise level, the sound pressure level of each frequency was lowered, and the noise was reduced to a maximum of 95 dBA. The employees' noise exposure time was reduced from 9 to 4 minutes because 95 dBA is considered high. The green area is where the noise level is appropriate, and the red area is where it is high. As a result, noise was reduced by 9.5% by turning off the buzzer during idle operation on the motor hoist.

4.3. Pneumatic Nut Runners

Due to the complex design of the engine, many noise issues of various origins occur within the pneumatic nut runners before and after, as shown in Figures 4 and 5. Most importantly, regarding the noise problem of the engine, pneumatic nut runners have been running with high noise.

(Before) (After)

Figure 4. Pneumatic nut runners of the engine

(Before-Wooden Load Carrier) (After-Metal Load Carrier)

Figure 5. Load carrier of the engine

In Figure 4, inside the engine compartment, the pneumatic nut runners have been replaced with quieter ones, and the wooden load carriers have been changed to metal load carriers to reduce the car engine acoustic noise as shown in Figure 5. Replacement of the pneumatic nut runner and load carrier has reduced sound pressure levels from 95 to 78 dBA. The noise intensity has been reduced by 17.9% at the new status.

4.4. Concrete Slabs

Load carriers, forklifts, transport cars, and lifts cause noise while driving over concrete slabs. Expansion joints have been implemented to reduce noise, as shown in Figure 6.

(Before) (After)

Figure 6. Renewal of concrete slabs

Expansion joints have reduced sound pressure levels from 94 to 85 dBA. The noise intensity has been reduced by 9.6% at the new status.

4.5. Internal Logistic

Both LPG engine forklifts and handle cars are considered transportation options in internal logistics. Electric forklifts generate less noise than LPG forklifts due to their quieter operation. Therefore, replacing the LPG forklifts with electric ones has been decided. Moreover, drawbars were covered with rubber bearings for handle cars, and springs were changed with softer ones, as shown in Figure 7.

(Before) (After)

Figure 7. Changes in internal logistics

Handle cars, rubber bearings, and springs have reduced sound pressure levels from 85 to 74 dBA. The noise intensity has been reduced by 12.9% at the new status.

The contribution of the noise reduction was to improve the new status. Then, the resulting noise reduction was visualized through improvements in sound pressure levels, as shown in Figure 8.

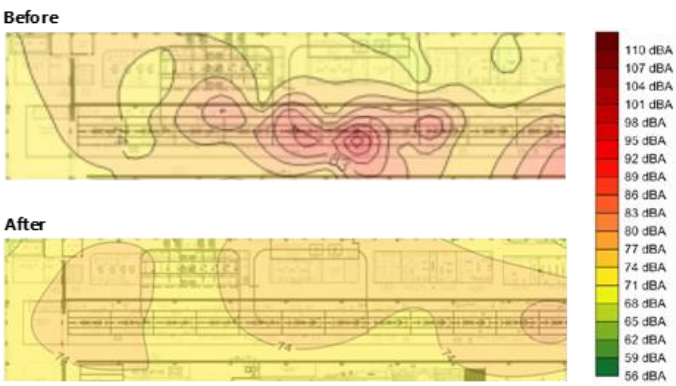


Figure 8. The new status pilot area

As a result of the studies, the overall noise level in the pilot area decreased to the target range. This result indicates that the noise level is below the target that could be achieved to prevent the usage of personal protective equipment. Measurements were taken 15 times, and distances between the noise source and the measuring device were maintained at 1 foot. The measurements conducted are presented in Table 4.

Table 4. Noise measurement (dBA)

	AGV	Motor crane	Pneumatic nut runner	Concrete slabs	Internal logistic
1	101	95	80	92	80
2	98	95	79	85	82
3	87	100	77	86	70
4	60	101	78	85	74
5	88	95	82	85	75
6	87	99	78	85	74
7	87	98	78	80	64
8	88	97	78	85	78
9	87	67	78	86	74
10	91	99	78	85	74
11	95	98	79	85	74
12	87	98	78	91	74
13	80	95	78	82	74
14	89	95	78	85	74
15	87	94	78	85	74
Average	87,47	95,07	78,47	85,47	74,33
Standard Deviation	8,86	7,78	1,15	2,80	3,93

The measures applied to assess the expected effects of a change in the sound pressure level process resulted in improvements as follows. Figure 9 shows the difference between the before and after situations.

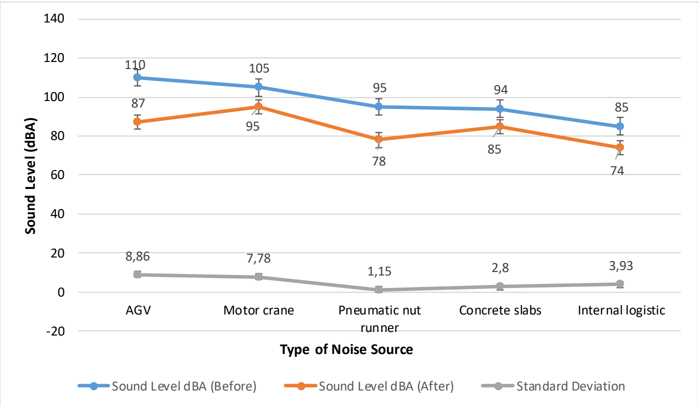


Figure 9. Sound level variation in noise sources after noise reduction

The literature aimed to improve the effectiveness of noise reduction in the automotive industry through sound absorption. This study's results are consistent with related literature [6,10,20-22]. According to the case study, there was a 14.2% reduction in noise levels, reducing the need for mandatory PPE. Meanwhile, the noise reduction percentage for AGV is the highest among other noise sources, at 20.9%. Also, according to standards, sound-absorbing solutions have been applied to control noise above 85 dBA, and no PPE materials to control noise below 85 dBA.

5. Conclusion

Noise is a common cause of hearing disorders and occupational diseases in industry. Due to the negative impact on employees' health, reducing the main noise sources has become increasingly urgent. Although noise reduction is an important issue in the industry, previous research has not adequately addressed it, especially in the automotive industry. This present study aimed to improve the quality of the working environment by reducing the use of PPE and the noise level in a pilot area of an automotive assembly line. For this case study, we used noise measuring tools such as a Svantec noise dosimeter and a sound level meter. We took 15 measurements while maintaining a distance of 1 foot between the noise source and the measuring device. During the study, we created noise maps to compare the noise levels before and after implementing the proposed measures. This allowed us to verify if the measures were sufficient. This paper concludes with applications of techniques to reduce noise by the main five important noise sources. Results showed that the sound pressure levels were dropped from 110 dBA to 87 dBA and reduced by 20.9% on average for AGV; from 105 dBA to 95 dBA and reduced by 9.5% on average for Motor Crane; from 95 dBA to 78 dBA and reduced by 17.9% on average for Pneumatic Nut Runner; from 94 dBA to 85 dBA and reduced by 9.6% on average for Concrete Slabs, and from 85 dBA to 74 dBA and reduced by 12.9% on average for Internal Logistic. The average noise reduction for three of five noise sources is beneath 85 dBA. Meanwhile, the noise reduction percentage for AGV is the highest among the five noise sources, at 20.9%. Results showed that the sound pressure levels dropped from 110 dBA to 87 dBA and reduced on average for AGV. The case study showed a 14.2% reduction in noise levels, which helped ensure the safety of employees by reducing the need for mandatory PPE. When noise levels are below 85 dBA, using PPE is not required. In addition to sound pressure level and noise reduction, a map was created with the noise level in the case area before and after the noise reduction strategy. Reducing reliance on PPE and implementing noise reduction measures enhances pilot area safety and contributes to a more ergonomic and sustainable work environment.

This case study contributes to the automotive industry and literature due to its novel approach. Therefore, the research results can foster dissemination and reduce the noise and use of PPE in industries. Furthermore, the noise reduction strategies outlined in this case study guide are for future studies.

Author Contributions

The first author managed the research endeavor, overseeing the entire study's progression. The first and second authors conceived the fundamental conceptual notions and formulated the overarching theoretical framework. Data collection from the case study was executed by the third author. Manuscript composition was spearheaded by the first author, with collaborative input from the second and third authors. The analysis, article composition, results documentation, and paper review and editing were undertaken collectively by all authors. The final version of the paper garnered unanimous approval following a thorough examination by each author.

Conflicts of Interest

All the authors declare no conflict of interest.

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