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ECONOMIC EFFECTS OF USING 5 IN + 1 H TOOL IN LIMITING THE NOISE SOURCES IN THE INTERNAL TRANSPORT

Abstract
In the paper the problems identified during the review and evaluations of correctness of applying safety at work regulations, and the correctness of the production processes on the production hall in the internal transport are analyzed. During the review a very high noise level which was close to the upper limit of the norm and amounted 83 dB in the production hall was verified [9]. To identify source problems a tool „5W+1H” was used – analysis 5 x why and Ishikawa diagram. Research results were a base of drafting the project of improving wagons for transporting production parts and components what allowed to lower the noise level in the production hall. In the project financial and immaterial benefits resulting from the project implementation were calculated, as well as few lowered occupational risks which occur in the unit. The project was carried out in a production unit in the household industry considering the data sensitivity the unit name where the project was carried out wasn’t revealed. An identification of economic effects as a result of eliminating the exaggerated noise sources made during the in-house components transport from magazines into the factory floors was a purpose of the project research.

JEL Classification Code: L15, M53.

Keywords: 5 in + 1 H tool, Ishikawa diagram.

Introduction
The internal transport in an enterprise carried out in the factory halls is without a doubt the area directly connected with the logistics. Usually it is made on low dis-

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tances, mainly at the section – spare parts warehouses – production lines – finished products warehouses or marked sections. The production halls among themselves and warehouses are connected with transport roads appointed for vehicles. These are tractors towing carts with parts and semi-finished products for the production, so-called „gitterboxes” (system of steel net containers), containers or other „packaging”. In the production halls forklift trucks for transport of palettes or containers of different kind are used more rarely. Considering the work safety regulations production halls are separated from warehousing facilities with special curtains, or barriers what is advisable for the workplace which is different on the warehouses area and production halls. The internal transport as the element of logistics carries a lot of threats and occupational risks associated with them which in case of production units may reach the number of a few thousand. Reducing the noise level and the number of risks is a result of studies described in the article. Obtained results were presented not only from the technical side but also in economic aspect, that is obtained benefits as a result of work and safety actions. Benefits were calculated according to the comparative research made in various countries and production units. These are also benefits in the form of the profit.

1. Identification of causes and sources of the exaggerated noise in the internal transport

For years the management supervising the projects has believed that extra working costs in accordance with work and safety regulations can contribute to many benefits. Therefore in the unit are used:
- motivating systems in the social insurance,
- economic analyses in the entire area of the health and safety at work,
- cooperation with foreign companies, e.g. Japanese.

Frequent employees remarks about feeling the exaggerated noise in the production halls and warehouses caused making immediate decision by the management to exam this occurrence. An awareness was an additional motive for the management action, that amongst occupational diseases which in Poland annually are stated a few thousand, where on the third position is a long-lasting double-sided hearing loss.

Describing the reasons and sources for the exaggerated noise during the internal transport of parts, sub-assemblies and production elements from warehouses to production halls was the research purpose. Transportation equipments put through an examination are tractors and carts pulled by them. For determining costs incurred essential costs were taken for the project implementation. For determining the benefits experiences of such counties as USA, Germany, Switzerland were used.
2. Characteristics of studied area

Internal communications roads in the factory are assigned to the transport between warehouses and the production halls in which the assembly lines are situated. Mainly tractor carts with wagons and occasionally forklift trucks move on these routes. Communication roads are clearly signed with appropriate lanes and permanently marked by paint, warning and information boards. For the movement safety light and signal signs are used. Communication is held with the help of mechanical means of transport which in studied area once in 15-30 minutes cross over the roads providing the production components to the assembly lines. The main harmful factor to the health in studied area is the noise. 15 sites, in which exceeding of the NDS and NDN pulses weren’t stated were controlled. However a very high noise level close to acceptable was reported.

![Site plan of studied area](image1.png)

*Picture 1. Site plan of studied area. On the plan points of the noise measurement were marked.*

*Source: own study.*

In studied area in the hall where the transport road is situated from which the noise source comes works about 100 people, including 15 people in the transport. Along transport roads tractors with wagons and forklift trucks are moving with maximum with speed up to 8 km/h and at intervals of about 30 minutes.
In studied area the internal transport infrastructure includes:

- internal roads,
- tractors (CXT) towing wagons (picture 2),
- wagons and carts - to transport production parts and details – 5 kinds,
- auxiliaries.

![Picture 2. CXT tractor with wagons of different type in the production hall](image)

Wagons and carts which are used to transport:

- small details - in containers of the gitterbox type or cartons,
- electric engines,
- panels (picture 3),
- blanks,
- casings,
- other components.

![Picture 3. Cart for the panel elements transport](image)
Achieved results required implementing new standards. Effects of the project were organized by establishing uniform standards for multiple applying by employees in the scope described in the picture 4.

![Image](image_url)

**Picture 4.** Standardization for the fulfilled purpose.
Source: own work according to the results of executed project.

In the framework of new standards after eliminating noise causes and reducing it to level of 77 dB the following standards were implemented:
- sharing the knowledge - spreading the knowledge in all areas where the same problem appears,
- monothematic lessons - internal training to reinforce the knowledge concerning only this problem
- before and after - shows the state of the problem before revealing the problem and after its solving in order to show clearly what has changed as a result of solving the problem,
- TPM card - is a help in conservation and inspections. It determines how to perform activities properly, with the help of what tools but also when the activity should be performed (More: Abramowicz, 2015), (1)
- inspections schedule.

As a result of standardization another appearance of the solved problem is prevented, however it requires entering into DTR additional legacies associated with adapting carts to requirements established as the project result.
3. Research methodology

Unit internal transport supports mainly the core activity process and is closely associated with it (Abt S., 2001). The system of spatial-temporary goods change determines logistic processes occurring in production companies (Pfohl, H.CH., 2001).

Production companies focus on the effectiveness of logistic processes, managing them and in connecting with other companies (Pisz I, Sęk T., Zielecki W., 2013). To solve the problem pointed in the article the case study approach was applied.

There are many methods which are possible to apply to analyze the correctness of applied solutions in the outside and internal transport. Methods allow to identify problems with different tools like e.g.:
- 6S+1 system (More: Abramowicz, 2014),
- Kaizen,
- supermarket,
- spaghetti diagram,
- Ishikawa diagram,
- 5W + 1H,
- standardization.

The three last tools mentioned above (Ishikawa diagram, 5 in +1 H, standardization) will be applicable in the project which is described later in the article. Tool 5 in +1 H collects and organizes data and information, making analysis and establishing causes of the examined problem, which causes risk in the workplace and threats from the work and safety point of view. Name of 5 of W+1 H method comes from English words: What? Who? When? Where? Why? and How? Answering individual questions towards the mistake, or a problem appeared in the analyzed process. Answers to questions are given according to evidence of different kind, facts and figures. Usually before applying 5 in + 1 H tool so-called Ishikawa diagram is applicable which consists determining the examined problem on the principle „from general to detail”. This tool is also known as 5 M which means: men, methods, machines, materials, management. In practice the Ishikawa diagram establishes the hierarchy of causes, which means that it divides them according to importance of appearing.

4. Research results

For examining the problem duration was planned for 8 weeks. In five first weeks the research of the noise level of noise in 15 sites of the production hall and warehouses was planned. Moreover at that time analysis, location of sources and detailed noise causes were taken. During next 3 weeks removing stated irregularities and lowering the noise level according to the established purpose were planned.

The research was conducted step by step according to the following scheme:
– applying the Ishikawa diagram for analysis of source causes,
– the indicator definition to monitor and the purpose,
– analysis of source causes of the occurrence of the exaggerated noise. 5 in + 1 h,
– analysis of source causes (method 5 x why),
– planning and implementing actions eliminating source causes,
– monitoring of project results with reference to the established purpose,
– standardization,
– the purpose accomplishment,
– effects verification.
– costs and benefits.

As a result of made 5 M analysis (because of the place thinness the Ishikawa diagram wasn’t presented in the article) is that the source of the problem are 1 M – materials and 2 M – machines – carts. Remain M didn’t appear. In order to define the aim of the project measurements to find the noise level were made. In the area of tractors with wagons ride 15 sites were set. Measurements let to establish that 4 kinds of tractor compositions generate the maximum noise on 83dB level. Consolidated results of the noise measurement were shown in picture 5. According to the work and safety principles of the noise, even though the norm allows noise of 85 dB level. a noise exceeding 80 dB causes discomfort in employees feeling. And so for the threshold of the adverse impact to the man 80 was accepted on 80 dB level. In that case an aim of achieving soundproofing the noise which doesn’t exceed 80 dB was presented to the team.

![Graph](image)

**Picture 5.** Monitoring the noise level in individual weeks (the first 5 weeks) and average weeks measurement results.

Source: own study based on measurement results.
In order to describe the detailed reasons for the set noise level following analyses listed in tables 1 and 2 were made.

Table 1. Analysis of source causes of the exaggerated noise occurrence. 5 in + 1 H

<table>
<thead>
<tr>
<th>5 W</th>
<th>Supporting questions</th>
<th>Answers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2. What has happened?</td>
<td>2. Employees complaints about feeling the high noise level on the hall and in the warehouse.</td>
</tr>
<tr>
<td></td>
<td>3. What specific thing/ the occurrence is it about?</td>
<td>3. Heable noise measured in dB</td>
</tr>
<tr>
<td></td>
<td>4. Does the problem change depending on applied materials, parts, their shapes or sizes?</td>
<td>4. The noise level changes depending on the pulled cart type. (Stil, Techmasz, Bewatec).</td>
</tr>
<tr>
<td></td>
<td>5. Are there any differences between provided parties?</td>
<td>5. No.</td>
</tr>
<tr>
<td>Where?</td>
<td>1. In which process does the problem occur?</td>
<td>1. It occurs by each completion of carts.</td>
</tr>
<tr>
<td></td>
<td>2. In which part/ section of the machine?</td>
<td>2. The noise is generated by: carts platforms, packages, connecting carts with shafts, wheels on dilatations</td>
</tr>
<tr>
<td></td>
<td>3. Does the problem change depending on applied machines/ tools?</td>
<td>3. The noise level changes depending on the pulled cart type: quiet - Stil, noisy - Techmasz, very noisy - Bewatec.</td>
</tr>
<tr>
<td></td>
<td>2. Has the occurrence the constant character?</td>
<td>2. Yes.</td>
</tr>
<tr>
<td></td>
<td>3. Does the occurrence appear at the beginning, in the middle or at the end of shift?</td>
<td>3. During the entire shift.</td>
</tr>
<tr>
<td></td>
<td>5. During which operations does the occurrence of the exaggerated noise appear?</td>
<td>5. During delivery the part by carts,</td>
</tr>
<tr>
<td>Why?</td>
<td>1. Why does the problem appear? Causes.</td>
<td>1. The noise level increases along with growing the number of pulled carts as a result of the rising purchases.</td>
</tr>
<tr>
<td>What for?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>How?</td>
<td>1. How does it come to appearance of increased noise?</td>
<td>1. The occurrence of the noise is as a result of tractors with carts rides.</td>
</tr>
<tr>
<td></td>
<td>2. Does the noise increase or reduce? and does it occur often or occasionally?</td>
<td>2. The noise occurs in the interval of 30 minutes, during the tractor with carts ride</td>
</tr>
<tr>
<td></td>
<td>3. Does the noise occur suddenly or is it intensifying?</td>
<td>3. The noise occurs constantly,</td>
</tr>
</tbody>
</table>

Source: own study based on information from the project.
Table 2. Analysis of source causes (5 of x why method).

<table>
<thead>
<tr>
<th>5 x W</th>
<th>Answers</th>
</tr>
</thead>
<tbody>
<tr>
<td>What?</td>
<td>Noise of the tractor with carts</td>
</tr>
<tr>
<td>Where?</td>
<td>In all tractor compositions</td>
</tr>
<tr>
<td>When?</td>
<td>While using carts</td>
</tr>
<tr>
<td>Why?</td>
<td>Faulty carts, bad road surface</td>
</tr>
<tr>
<td>How?</td>
<td>The noise level increases along with the rise of the number of carts in composed</td>
</tr>
</tbody>
</table>

Source: own study based on information from the project.

Knowing detailed causes of the searched noise level additional actions in order to eliminate source causes were planned. Next monitoring the project results with reference to the established purpose were made. Sources causes are presented in picture 6 on the left. And the way of establishing preliminaries in analysis of causes is presented in picture 6 on the right.

![Planning and implementing actions to eliminate source causes (A, B, C, D, E, F, A1, B1, C1, D1, E1, F1).](image)

Source: own study.
In picture 6 one by one ways of eliminating pulses in the cart connections were presented:
- riveting down and sticking the tin-shelf which by pulses would cause unnecessary noise,
- adding the gasket on the connection which mutes pulses and its fastening,
- adding the soundproofing mat to the shelf from its bottom side which mutes pulses of the shelf,
- screwing - establishing the stable correct position of the screw,
- adding the muting gasket of the cart shaft,
- repairing backer cracks in internal routes.

[Graph showing noise levels over time]

**Picture 7.** Results of noise measurements before the removal (the first 5 weeks), during removing (6, 7 and 8 week) and after removing the occurrence of the exaggerated noise (9th week).
Source: own study based on project data.

As a result of removing the two first irregularities described in pictures 6 point A and B, in 6th week of the project duration a noise level was gained on 80 dB level. In the next, 7th week after removing next irregularities (picture 6 C, D, E) the noise reached a level of 78 dB. In the last week the last irregularity was removed and a noise was on level of 77 dB. To make sure about for the correctness of the received result in the 9th week finishing the project the noise level was checked again. Measurements showed level of 77 dB.
5. Technical and economic results

Accomplishment of the purpose even though which involved the need to incur determined costs brought results of lowering the noise level and lowering the increased indicator risk. Results are shown in table 3. The project implementation required investing financial means in amount of 14 500 PLN. Value of labor and applied materials used in the project are shown in table 4.

Table 3. List of achieved results.

<table>
<thead>
<tr>
<th>No.</th>
<th>Name of the project indicator</th>
<th>Noise value (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Before project</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Aim</td>
</tr>
<tr>
<td>1</td>
<td>Lowering the noise</td>
<td>83</td>
</tr>
<tr>
<td>2</td>
<td>Lowering the increased indicator risk</td>
<td>19</td>
</tr>
</tbody>
</table>

Source: own study based on findings.

Table 4. List of the project implementation costs for 8 wagons

<table>
<thead>
<tr>
<th>No.</th>
<th>Material and labours kinds</th>
<th>Material and labor value (in PLN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Metal sheet</td>
<td>340</td>
</tr>
<tr>
<td>2</td>
<td>Glue for sticking the metal sheet to the frame</td>
<td>550</td>
</tr>
<tr>
<td>3</td>
<td>Soundproofing mat</td>
<td>780</td>
</tr>
<tr>
<td>4</td>
<td>Sealing materials</td>
<td>560</td>
</tr>
<tr>
<td>5</td>
<td>Nuts and screws</td>
<td>365</td>
</tr>
<tr>
<td>6</td>
<td>Rivets (exchange of aluminium rivets into metal rivets)</td>
<td>355</td>
</tr>
<tr>
<td>7</td>
<td>Stiffening trusses</td>
<td>1 925</td>
</tr>
<tr>
<td>8</td>
<td>Filling the road dilatation in the production hall</td>
<td>2 425</td>
</tr>
<tr>
<td>9</td>
<td>Labour (60 x120 hours PLN)</td>
<td>7 200</td>
</tr>
<tr>
<td>10</td>
<td>Together</td>
<td>14 500</td>
</tr>
</tbody>
</table>

Source: own study based on data of examined unit.

Indicators calculated for similar „work and safety investments” made in Germany and in Switzerland were used to calculate the estimated profit - benefits from investments made to fulfil the project. In the first case he indicator was 1.6  which means, that each 1 PLN intended to implement the project should give a benefit (profit)  of 1.6 PLN in the future. In the second case  the estimated benefit will bring 2.2 PLN for each invested 1 PLN. These results are presented in table 5.
Table 5. List of costs and benefits

<table>
<thead>
<tr>
<th>No.</th>
<th>Amount of the work and safety expenditure (PLN)</th>
<th>Benefit ratio (PLN)</th>
<th>Benefit (PLN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>14 500</td>
<td>1.6</td>
<td>23 200</td>
</tr>
<tr>
<td>2</td>
<td>14 500</td>
<td>2.2</td>
<td>31 900</td>
</tr>
</tbody>
</table>

Source: own study.

Comparing both results it is possible to state that irrespective of the indicator admitted to estimating benefits are significant.

Summary

Information from employees suing to the excess noise level in the production hall and in the warehouses led to make a rational decision to locate noise sources. For solving this problem a team of employees was appointed which drew up the project of improving existing state of supplying parts and components for production. Presented studies are a result of conducted analysis with use of the Ishikawa Diagram and 5 in + 1 H (five why + they how) tools. The project Implementation let to eliminate the troublesome, high noise level. It is needed to underline the fact of disproportionately low cost of the project implementation compared with costs of possible hearing loss of employees working in the examined area. Issues of the internal transport are these which demand rational decisions in aspiring to improve its functioning. Due to the need of providing safe transport processes.

It is needed to remember, that in processes of the flow being an essence of the contemporary logistics which include transport processes which always, in smaller or larger level, accompany production processes, create about 30% of the company profits (Korzeń Z, 1998). The solution suggested in the article will also constitute the appropriate particle of the company profits.

References


PN-N-01307 (zamiast PN-84/N 01307),(1994), *Dopuszczalne wartości hałasu w środowisku pracy.*