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The Concept of Integrating Interactive Safety Signs into In-Plant Traffic Flow Optimization and Safety Management

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Abstract: Modern manufacturing companies are characterized by complex internal traffic processes, both pedestrians and forklifts. This results from frequently changing machine locations and thus internal routes, but also from specific production needs, e.g. in the context of customer requirements. Such dynamically developing processes cause problems with ensuring the safety of employees who must move particularly carefully in the production halls. The answer to these problems may be interactive safety signs, which increase employees' attention to dangers, but require a lot of resources for their correct installation. This article presents the concept of implementing interactive signs on the example of a selected production hall. Based on its implementation, a discussion on the required time and cost resources for their installation is also presented in comparison with the benefits and barriers to this implementation.

Keywords: interactive safety signs; occupational health and safety; safety management

1 INTRODUCTION

Nowadays, safety in the workplace is becoming crucial, especially in industrial environments such as production halls. These are places where complex technological processes, intensive machine work and a large number of employees create potential hazards. Therefore, it is so important that every aspect of work organization is well thought out and complies with applicable safety standards. In this context, safety signs play a fundamental role in communicating hazards and educating employees on the proper procedures to act in emergency situations. Safety signs inform about dangers, indicate evacuation routes, and remind people to wear appropriate personal protective equipment [1]. They can also be a factor in preventing accidents at work by providing appropriate information (it can be pointed out that many accidents are caused by organizational factors, such as insufficient provision of information about the hazard) [2, 3].

Typically, the most popular horizontal signs are used in companies, installed on floors, on walls and columns of production halls. It is certainly the easiest solution to provide information about the evacuation route or hazard, however, employees often do not pay due attention to them. It is certainly crucial to install signs of the right size for the place of installation and to select the right sign for the message being conveyed. In order to engage employees in receiving information presented through signs, interactive signs are increasingly used, which are more visible to the employee and at the same time engage them by providing an element of curiosity about the specific operation of individual components [4, 5].

This article presents the concept of using interactive safety signs in the context of managing traffic inside a selected production hall. The first phase of the research was to analyze the possibility of installing such safety signs, taking into account the location of machines and communication routes. Then, a proposal for the location of interactive signs was presented, together with an indication of the resources necessary for this installation. The conducted research allowed to determine the possibility of using interactive signs in the management of internal traffic (pedestrians and forklifts) in a place defined as particularly dangerous from the point of view of the location of communication routes and gates. The impact of the applied solutions on the occurrence of accidents in this place and encouraging employees to move in accordance with the established rules was also determined.

2 SAFETY SIGNS IN THE CONTEXT OF MANAGING IN-PLANT TRAFFIC

2.1 Legal Requirements for Safety Signs

Council Directive 92/58/EEC defines safety and/or health signs as *signs referring to a specific object, activity or situation and providing information or instructions about safety and/or health at work by means of a signboard, a color, an illuminated sign or acoustic signal, a verbal communication or a hand signal, as the case may be*. It also indicates the division of signs and the need to use them in situations that require providing employees with understandable messages [6]. Many international and national legal regulations indicate the need to inform employees about hazards and the required behavior in a given place. Safety signs are partly standardized by the ISO 7010:2020-07 standard, which is part of the international signage system. This document contains a set of standard graphic symbols that are used to communicate information about hazards and safety rules. Signs are divided into the following categories: prohibition, warning, order, evacuation, first aid, fire protection and information. Another division of signs refers to the transfer of information to recipients and indicates light, acoustic, verbal and hand-indicated signs in the absence of the possibility of providing a physical sign. By using appropriate colors and shapes, the signs are to be understandable to every recipient (even without knowledge of e.g. the language of communication) [7, 8].

2.2 Approaches Used to Provide Safety Signs

It is advisable to take into account the safety signs not only due to legal requirements, but also for the purpose of obtaining other benefits, e.g. making employees aware of the most significant hazards identified in the production process or systemic management of traffic within the plant [9, 10]. Internal traffic management is implemented through communication between employees and the production and logistics system (including internal transport) in terms of determining, for example, priority of passage, communicating hazards on the machine or the need to stop at a designated place before continuing to the destination [11]. Many companies provide standard horizontal signs, of appropriate size depending on where they are installed. This is a simple and relatively cheap solution due to the easy availability of signs (also with additional functions, e.g. fluorescent). The perception of these signs may depend on their size, but also on their color and whether they warn about a given type of hazard [12].

Current employee safety management requires the use of new solutions in the field of hazard information due to dynamically developing processes but also due to employees becoming accustomed to standard safety signs (which often results in them being omitted). Companies are increasingly using interactive signs to enhance the effect of influencing employee behavior by creating an element of curiosity and ensuring that the sign operates at the right moment to focus attention (e.g. when a machine opens or a forklift passes by) [13]. The meaning of messages conveyed through signs and how they work is presented to employees during training and in direct conversations with their superiors [14]. The examples of the interactive sign are shown in Fig. 1-3.

Figure 1 Example of interactive safety sign [15]

Figure 2 Example of interactive safety sign [own photography]

Figure 3 Example of interactive safety sign [own photography]

By displaying signs as intended, it is possible to inform employees about important aspects of the process (mainly hazards) but also to manage the traffic of e.g. forklift operators by passing on a message e.g. about when to stop. It can therefore be indicated that information signs will perform various functions in managing internal traffic [15-17]:

- providing an information function for employees moving around the production hall on foot (e.g. "STOP" signs, warning about a forklift passing by, order to use personal protective equipment),
- causing forklift operators to stop, e.g. at intersections or places of increased pedestrian traffic,
- traffic management by indicating e.g. places prohibited for pedestrians or additional crossings (additional illumination of their course),
- additional lighting at intersections where an accident or collision may occur,
- informing about the possibility of passing by the machine or the impossibility of doing so, e.g. due to the delivery of goods or ongoing repair or maintenance activities.

Often, signs are installed in a way that allows them to be activated only when movement is detected on internal roads. This results in savings related to the lack of their continuous operation but also increases the employees' attention to their appearance.

In the undertaken research the case of the possibility of using an interactive intersection was analyzed. The problem and its proposed solution are presented graphically in Fig. 4.

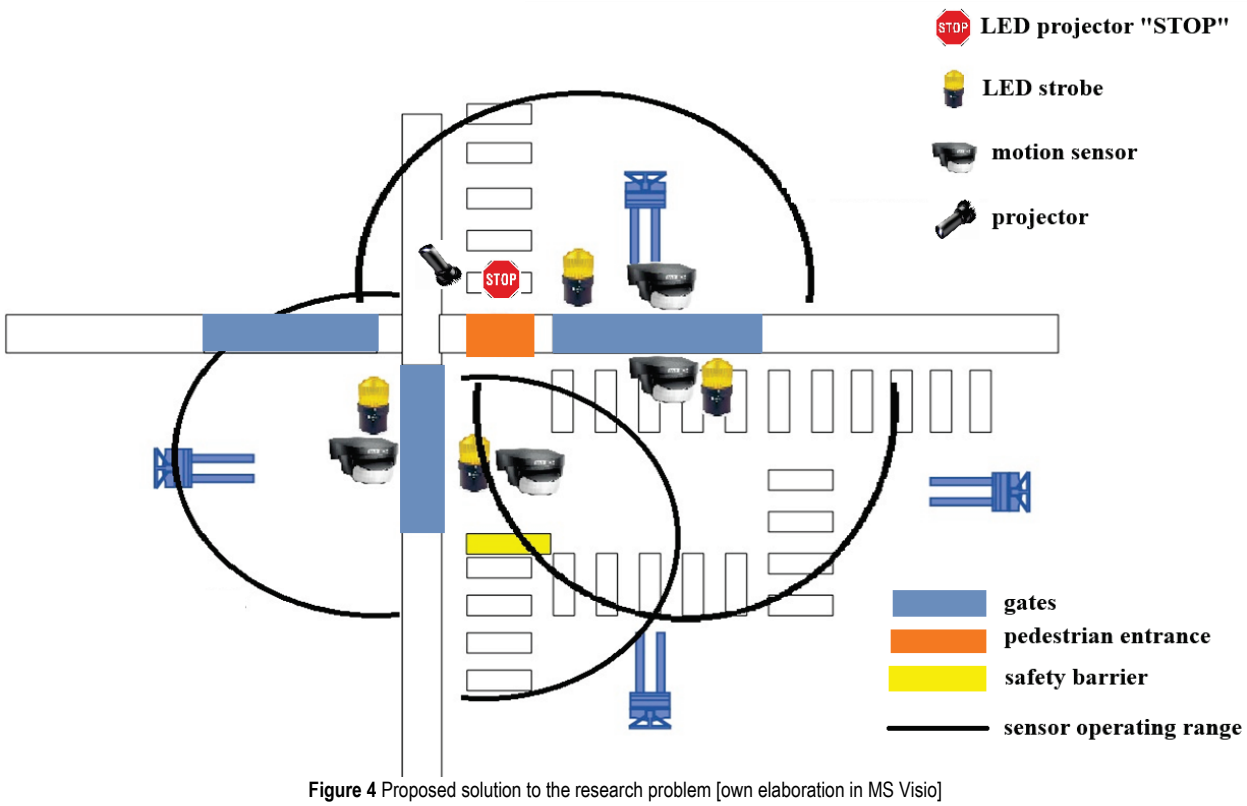

Figure 4 Proposed solution to the research problem [own elaboration in MS Visio]

3 METHOD OF RESEARCH

The research undertaken was aimed at solving the problem of increased internal traffic in a selected location in the company through the appropriate use of interactive signs. The main problem identified was the close location of three transport gates (where forklifts move) and pedestrian crossings near these gates. Approximately 200 pedestrians and 35 forklift operators take part in internal traffic during a work shift. The machines are located directly next to the communication road (approx. 70 cm) on the side of the pedestrian crossing.

The following project implementation results were assumed:

- directing pedestrian traffic on designated roads so that they choose a pedestrian crossing in the appropriate direction of moving,
- ensuring that forklift operators are informed about pedestrians moving on the road,
- ensuring that signals are understandable to both pedestrians and forklift operators and clearly visible,
- combining the operation of all elements of the proposed solutions (sensors and projectors) with simultaneous cost reduction and their operation only when traffic is detected on internal roads,
- ensuring the possibility of training all participants in internal traffic in the operation of the proposed solution in order to eliminate errors in the reception of transmitted information.

Due to the location of the gates and pedestrian crossings, it was decided not to provide only standard horizontal signs informing about the way of moving and caution. However, they were also installed from the point of view of meeting the requirements of legal regulations.

The solution to the problem presented in the article was developed in cooperation with process engineers and employees moving around the hazardous area on a daily basis, which had to be additionally marked. The following sections describe the mechanism of operation of the proposed solution as well as discuss its effectiveness and implementation barriers.

4 RESULTS

The presented solution assumes the safety of pedestrians and forklift operators at a particularly dangerous intersection due to the proximity of three gates and pedestrian crossings. A solution was proposed, which is a combination of several LED strobes and a projector displaying the "STOP" sign at the pedestrian crossing before entering the communication route. The operation of the devices presented can be described as follows:

1) In the event of a forklift approaching the intersection, the motion sensors detect it and activate the stroboscopes, which inform pedestrians about the hazard (using an orange light) that may appear on the road while they are crossing the pedestrian route.
2) In the case of informing forklift operators about pedestrians on the other side of the gate, the solution works on a similar principle - if a pedestrian appears, the

motion sensor detects it, informing the forklift operator about it with an orange light. The motion sensors detect a pedestrian entering the pedestrian crossing, so the operator has enough time to react if the signal appears.

3) The most dangerous exit to the described internal road was the entrance, where it was required to provide an additional sign about stopping before crossing the door. A LED "STOP" sign with a projector displaying it was provided there. If a forklift movement is detected on the other side of the passage, the large sign is displayed on the ground, urging the employee to stop and pay special attention to the movement of forklifts on the road. The sign appears only when a forklift movement is detected, so it does not appear all the time so as not to accustom employees to its presence (as in the case of standard horizontal signs).

Additionally, to increase safety, a barrier was installed at a greater distance from the intersection, which forces the employee to slow down when approaching the intersection. The approximate range of motion sensor operation is shown in Fig. 4. The methods of operation were determined based on measurements of the distance of the sensors from the gates and pedestrian crossings, as well as on calculations of the time required for the forklift operator to stop or slow down enough to avoid a collision with a pedestrian near the pedestrian path.

The implementation was completed with employee training explaining the operation of the proposed improvements at the intersection and on the traffic routes. While the operation of the projector and the "STOP" sign was understandable to everyone, the operation of the visual aspects (orange lights) had to be thoroughly explained and presented in real conditions.

5 DISCUSSION

The presented solution of installing an interactive sign and light signals made it possible to achieve the implementation goals, which were mainly to increase safety and manage internal traffic in a selected area with increased risk. Employees were informed about how to move around this area, and their attention was also drawn to threats through an interactive element. In relation to in-plant traffic management, it became possible to direct the movement of forklifts in terms of adjusting the speed to pass through gates and to exercise caution in the context of the possibility of pedestrian traffic on pedestrian paths near gates.

Despite achieving the goal, it is possible to indicate many implementation limitations that resulted from the need to provide appropriate resources and the analysis of benefits in relation to standard solutions (e.g. providing horizontal signs). These limitations are presented in Tab. 1.

Taking into account the above-mentioned limitations of implementing a solution with interactive elements, it can be stated that it requires a detailed analysis in order to ensure an optimally functioning system, taking into account financial possibilities as well as the expected result of the implementation. Sometimes it may turn out that the adopted assumptions may not be met due to insufficient resources or limited employee involvement in the process.

Table 1 Limitations of the solution proposed in the analyzed case study

No.	Limitation	Analysis of the impact of the limitation on the final proposal to solve the research problem
1	Much higher implementation costs than providing standard horizontal markings.	Providing horizontal safety signs on the production floor is a relatively cheap solution. For this reason, in the case of the planned solution with interactive elements, an analysis of the benefits had to be carried out in relation to the higher costs to be undertaken (approx. 20 times higher). It was decided that the possible increase in employee safety is a factor that can compensate for the higher cost of implementing the proposed system.
2	The need to find and connect modules that provide detection of pedestrians and forklift movement.	It was decided that the solution would consist of separate modules and the whole thing was installed by maintenance engineers. Their task was to find the right devices and connect them, which increased the implementation time to several weeks.
3	The need to perform detailed calculations to determine the location of motion sensors.	Motion sensors were installed after calculating the time needed for a forklift operator to slow down or stop. Determining this time and distance applied to all gates and pedestrian crossings in the designated dangerous location. It was also necessary to determine the height and size of the light signs, as well as the distance of the LED "STOP" sign from the entrance door leading to the intersection.
4	The need to determine whether it is necessary to engage an external company to complete the order or whether it will be done internally.	It was decided that the implementation would be done internally by maintenance engineers due to the lower costs of interfacing the system components. This decision was preceded by obtaining offers from external companies in this area, which turned out to be much higher than matching different devices.
5	The implementation of the proposed system may not solve the problem of unsafe employee behavior and crossing the road in prohibited places.	Considerations were made on whether the implementation of the proposed solution would significantly affect the behavior of employees in the dangerous area of the intersection. People are the least predictable element of internal traffic, therefore it was wondered whether the costs incurred for the implementation would be adequate to the result obtained. The opinion on this subject was expressed by the employees' superiors, and a training element was also carefully planned after the solution was implemented. It was stated that the actions taken should contribute to increased caution on the part of employees. However, this requires verification after some time of using the solution in order to consider taking further actions to increase the awareness of participants in internal traffic.

Source: own elaboration.

6 CONCLUSIONS

Employee safety in the production process is an extremely complex issue because, in addition to organizational resources, it also requires the involvement of all participants in the issue of safety, from employees operating machines to their superiors. This is particularly important in the case of organizing internal traffic (pedestrians and e.g. forklift operators). One of the elements of ensuring their safety is to inform about threats and required behaviors in a given place, which can be done by providing appropriate safety signs. In addition to standard horizontal safety signs, it is possible to install interactive solutions, the advantage of which is certainly to provide an element of interest and greater visibility of a given threat.

As shown in the above example, solutions with interactive elements can be a response to identified problems in ensuring safety in places where there is increased traffic at dangerous intersections and pedestrian routes, which for technological or organizational reasons could not be routed in a different, safer way. The aim of their implementation is to increase employees' attention to threats by implementing systems to which they are not accustomed as they are to standard solutions. An additional advantage of such systems can be the management of internal traffic by influencing, for example, the direction of pedestrians or the speed adopted on a forklift. However, this requires that all elements be properly matched and installed at appropriate distances to properly detect movement and then transmit messages at the right time.

There is no doubt that implementing interactive solutions involves higher costs than in the case of standard safety signs. This is certainly one of the limitations of implementing such solutions, especially in production halls where there are many places that are potentially dangerous for employees. Another important limitation to consider is the need to find and connect appropriate modules in order to obtain the desired effects of introducing such a system. For this reason, each such improvement should be preceded by an appropriate analysis of the needs and possibilities of appropriately adjusting individual elements.

It should be noted here that in the era of dynamically developing artificial intelligence, safety solutions that go beyond the standard and requirements of legal regulations will increasingly appear in modern enterprises. Their recognition and implementation can facilitate faster adaptation to these changes by employees and also build a competitive advantage for the organization on the labor market.

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