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A CASE STUDY IN IMPROVING THE SAFETY OF COLLABORATIVE TASKS IN THE AUTOMOTIVE INDUSTRY

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Abstract: *The present paper presents a case study for riskassessment in collaborative work environments, performed on an automotive supplier company. The case study contains an OHS audit, a risk assessment and mitigation method applied to the risks identified during the audit, and a discussion of the research gap in adapting risk management models to the new technologies and approaches. The case study is based on international standards such as ISO 45001:2018, ISO/TS 15066:2018, ISO 10218:2018, and ISO 12100:2010 and applies a risk mitigation model based on the Pilz factor.*

The study concludes that even if procedures, training programs, and safety measures are designed and applied and everything seems to work very well in theory, in practice other risks can appear caused by unauthorized operator interventions, for example, and new operational frameworks have to be designed.

Keywords: *Risk assessment; Risk mitigation; Automotive industry; Collaborative robots; Collaborative tasks; Collaborative work environments.*

1. INTRODUCTION

Collaborative tasks performed within collaborative work environments are common in the automotive industry and most assume the common presence and the purposeful interaction of machines, robots, and other technical systems with human operators and other workers, in order to achieve production goals. Besides the results and productivity, the safety of the operators has an important role in these companies and the top management must implement a risk management process and perform periodic audits and analysis to prove the efficiency, using instruments such as [1-3]: FMEA (Failure Modes and Effects Analysis), FTA (Fault Tree Analysis), BN (Bayesian Networks), FPN (Fuzzy Petry Nets), RM (risk matrix), etc. Most of the time, these tools are implemented with the support of dedicated software packages, containing specific knowledge bases. This analysis must be performed from the beginning of the product lifecycle until the end, from the design process to the end of life and in this way the companies will show agility and resilience over time [4-5].

One of the relevant examples of a problematic area, linked to the research and digitalization, are the robotic cells with collaborative tasks, where the people and the robots work together to perform a job, either with operational purpose or for the needs of the production system, such as programming or maintenance. In case the process is not stable or safe enough, the system or the robots can deviate from the standard parameters and possible risks start to materialize in the form of defective products, inefficient processes, downtimes, operator injuries, and, in the worst-case scenario, injury or death of the operators. The highest risks are mainly related to the fourth and fifth industrial revolution technologies because of the dynamic and complex risks associated with these [6].

This paper is based on our previous research articles, on literature review concerning risk management and a conceptual framework developed based on international standards and has the aim to validate it through a case study performed on a company that manufactures and supplies parts in the automotive industry, for car producers.

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2. MATERIALS AND METHODS

The practical study is based on the research methodology below, specific to the field of industrial risk management (Figure 1). The first step is based on previous studies and experience in the risk assessment area [7]. Based on this, the OHS audit was performed to start the risk assessment and mitigation process.

The cases have been presented in a walk-through format, highlighting both the situation and the results.

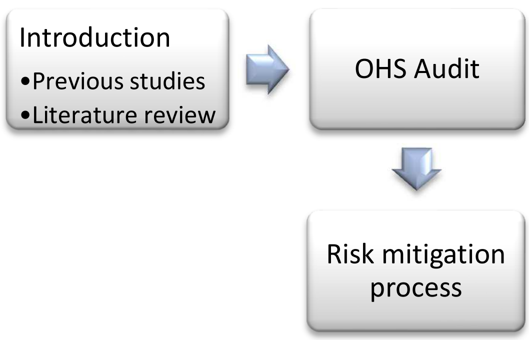

Fig. 1. Research methodology

3. CASE STUDY IN THE AUTOMOTIVE INDUSTRY

The case study was performed on an automotive company that applies collaborative tasks in the manufacturing process [8]. The focus was on the robotic cells and smart processes where the previous conceptual framework [7] could be tested for relevance. The first step was to identify the proper company, present the intention of the study, and get approval from the top management to perform the case study, based on an audit plan. The company contacted has a 360° manufacturing process that takes place in three manufacturing plants.

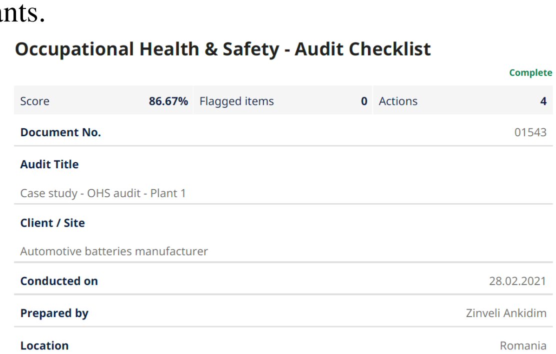

Fig. 2a. OHS audit summary

The next step was to perform an Occupational Health & Safety (OHS) audit on the interest areas, to identify the possible risks, using the checklist provided by the online platform www.safetyculture.com [9]. The audit summary can be seen in Figure 2 and the risks identified and actions needed are presented in Figure 3.

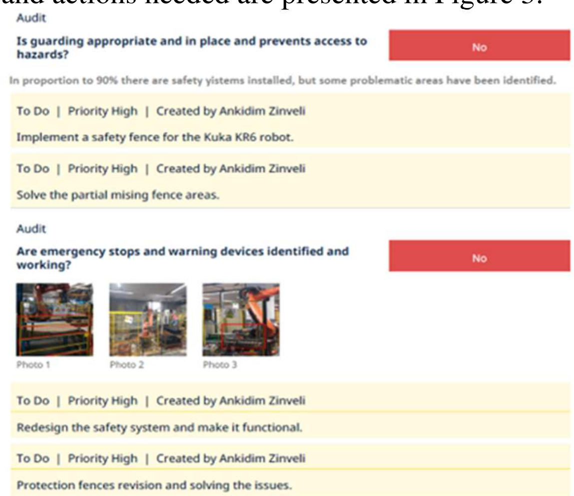

Fig. 2b. OHS audit main actions

For the risk assessment and risk mitigation process, we used the Robotiq Inc. model [10]. The approach was developed by the company Robotiq Inc. for risk analysis in the form of a Microsoft Excel file, based on a PILZ© factor format and the international standards ISO/TS 15066:2018, ISO 10218:2018 part 1 and 2, and ISO 12100:2010 [8], [11]. The first steps are allocated to identifying and describing the robots and machines' specifications, the operating modes, and all the interactions between them and the human operators during collaborative tasks in the collaborative work environment. The next step is represented by the risk estimation process using the PILZ© criteria and audit-based observations and interviews, by evaluating four main factors: Degree of Possible Harm (DPH), Probability of Occurrence of a Hazardous Event (PO), Possibility of Avoidance (PA) and Frequency and/or duration of Exposure (FE) [10-11] and using the formula [10]:

$$PHR = DPH \cdot PO \cdot PA \cdot FE \qquad (1)$$

The factors have different evaluation scales, and the risk rating can take values between 1 (the lowest risk rating) and 9750 (the highest risk rating), highlighted by the colors: green (1-10), yellow (11-45, two levels), and red (46 and above, three levels) [10].

Hazard Identification		Hazard No.	3
Title	Pelletizing process - end of the line		
Target	Hand / Arm / Had		
Activity	Normal Operation		
Task	Closing and release of the gripper during the handling process. Robot positioning.		
Hazard Type	Crushing and impact (Quasi-static)		
Description	On the stacking area, at the and of the line, there is a small area (about 400 mm) without a safety fence or other safety method. The operators are trained to not enter this area. Even if there are safety makings, the operators are trained, and because there is no automatic stop system it is possible to have unauthorized interventions and hazard appears. In case one operator would introduce his hand, or arm or have inside, the gripper could break his fingers, or the robot arms could injury him.		
References:	ISO/TS 15066, ISO 10218		
Risk Estimation and Evaluation			
Degree of Possible Harm:	3	Possibility of Avoidance:	2,5
Probability of Occurrence of a Hazardous Event:	2,5	Frequency And/or Duration of Exposure:	4
Pilz Hazard Rating (PHR):	75	Summary Level:	Significant Risk
Risk Reduction			
There is a significant risk to health and safety and risk reduction measures are needed. To improve safety it is required to implement an optical barrier that would automatically stop the robot in case of any unauthorized actions. Another less complex solution could be to extend the protection fence and close this area.			
Risk Estimation and Evaluation			
Degree of Possible Harm:	3	Possibility of Avoidance:	0,75
Probability of Occurrence of a Hazardous Event:	0,5	Frequency And/or Duration of Exposure:	0,5
Pilz Hazard Rating (PHR):	0,5625	Summary Level:	Negligible Risk

Fig. 3. Risk identified during the case study - example 1

The described methodology was used to perform a deep analysis for all the risks identified during the OHS audit for collaborative work. Two representative examples of how they were identified and treated can be seen in Figure 3 and 4 [8].

Hazard Identification		Hazard No.	8
Title	Splash with hot adhesive		
Target	Hand		
Activity	Normal Operation		
Task	Apply melted adhesive according the program.		
Hazard Type	Burn / injury		
Descrpition	The KR 6 robot dispenses melted glue at default points according to the software program. This glue is very hot. The start of the process is carried out by an operator who knows the process very well. Due to the fact that there is no proper safety system, even if the operator is trained, there is a possibility that the hand or other part of the body will reach the working area of the robot and get burned by the hot adhesive.		
References:	ISO/TS 15066, ISO 10218, BS EN ISO 12100:2010		
Risk Estimation and Evaluation			
Degree of Possible Harm:	0,5	Possibility of Avoidance:	5
Probability of Occurrence of a Hazardous Event:	2,5	Frequency And/or Duration of Exposure:	4
Pilz Hazard Rating (PHR):	25	Summary level	Low Risk
Risk Reduction			
The risk level is low and the health and safety of the operator is not so high affected but risk reduction measures are required. To increase the safety into this area, it is recommended to install a protective fence or optical barriers that will automatically stop the robot in case of unauthorized intervention. Until new systems are implemented, periodic training of operators is recommended.			
Risk Estimation and Evaluation			
Degree of Possible Harm:	0,5	Possibility of Avoidance:	0,75
Probability of Occurrence of a Hazardous Event:	0,05	Frequency And/or Duration of Exposure:	0,5
Pilz Hazard Rating (PHR):	0,009375	Summary level	Negligible Risk

Fig. 4. Risk identified during the case study - example 2

This analysis is supported by the process description, the robot specifications, the observed interactions with the operators and other machines, the working parameters, and other relevant data from the process (e.g., productivity, downtime, non-conformities, etc.). As can be observed, the risks have a high score but after the implementation of the proposed actions (optical barriers, protection fence, training), the risk score decreases considerably, and the process becomes safer.

4. CONCLUSIONS

Based on the case study, the research undertaken found that the conceptual framework that is sound in theory and positively influences process design, the procedures, the training programs, and the safety measures, must also contend with real unforeseen risks like operator interventions in the system, unreported incidents, surprise audits and inspections, and miscalculation of safety incident costs as opposed to productivity costs related to the collaborative operations. Accepting that Industry 5.0 will become more desirable soon, one must take into account that unknown risks will appear and be missed completely if an enhanced understanding is not soon developed. The international standards in the risk management area are not compatible at this time with future Industry 5.0 technologies and approaches and even observing the principles behind this concept is in a rather blurry area at the moment.

Collaborative tasks become more common every day in the automotive industry increasing the interaction between operators and robots, machines, or vehicles. The main limitations of this work are related to its specificity, which is limited to one company and the missing reference on how the new categories of risks can be described and understood. Further on, the model can be extended based on the instruments from the other existing international standards not used so far such as ISO/TR 14121-2:2012, IEC 31010:2019, COSO ERM or other frameworks such as PMI (Project Management Institute) for general evaluation or the NIST Cybersecurity Framework for one of the specific topics, in this case protection of the IT infrastructure.

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Studiu de caz în îmbunătățirea siguranței sarcinilor colaborative din industria auto

Rezumat: Prezenta lucrare prezintă un studiu de caz privind evaluarea riscurilor în medii de lucru colaborative, realizat într-o companie care furnizează componente producătorilor de automobile. Studiul de caz conține un audit SSM, o metodă de evaluare și atenuare a riscurilor aplicată riscurilor identificate în timpul auditului și o discuție despre decalajul de cercetare în adaptarea modelelor de management al riscului la noile tehnologii și abordări. Studiul de caz se bazează pe standarde internaționale precum ISO 45001:2018, ISO/TS 15066:2018, ISO 10218:2018 și ISO 12100:2010 și aplică un model de diminuare a riscurilor bazat pe factorul Pilz.

Studiul concluzionează că, deși procedurile, programele de instruire și măsurile de siguranță sunt concepute și aplicate și totul pare să funcționeze foarte bine în teorie, în practică pot apărea și alte riscuri cauzate de intervențiile neautorizate ale operatorilor, de exemplu, și trebuie să fie dezvoltate noi cadre operaționale.

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