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LITERATURE REVIEW CONCERNING SAFETY RISK ASSESSMENT IN COLLABORATIVE ENVIRONMENTS

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Abstract: *The present paper addresses the issue of risk assessment in collaborative work environments specific to Industry 4.0, where robots and human operators must work together, in the automotive industry. The investigation methodology uses a literature review in the field, combined with a comparative analysis of reference standards based on interviews with industrial partners. The ranking of criteria is achieved using the AHP method and a combined conceptual framework is developed using the Pugh Concept Selection method. The study concludes that current references can be combined and extended based on new industrial principles, but this is a short-term solution, as the new challenges of Industry 5.0 will soon become a reality.*
Keywords*: Risk assessment; Automotive industry; Collaborative robots; Collaborative tasks; Collaborative work environments.*

1. INTRODUCTION

The automotive industry is one of the most affected sectors by last year's global negative events such as the COVID-19 pandemic, the global microchip shortage, wars, resource limitations, and urgent alternatives are needed. Besides these events, market changes due to higher customer expectations and increased product customization trends, as well as costs rising due to inflation, also had a high negative influence on the automotive industry because higher productivity and more advanced processes are needed. Some solutions in this aspect are provided by the new technologies, mostly revolving around automation, robotization, and data analytics, linked to Industry 4.0 and Industry 5.0 [1-2]. Risk management has a very important role in this situation because using this instrument the companies can develop agility and resilience for quick business recovery and problem-solving, starting from the product development and prototype phase, throughout the entire lifecycle of the product [2-3]. The safety of the operators and the sustainability of the processes must be assured by implementing risk management and performance management processes that will ensure that the tasks of risk identification, risk evaluation, risk documentation, and action plan implementation, can be achieved using tools like [4-6]: FMEA (Failure Modes and Effects Analysis), FTA (Fault Tree Analysis), HAZOP (Hazard and Operability Study), RPN (Risk Priority Numbers/Scores), SCEA (Safety and Critical Effect Analysis), BN (Bayesian Networks), FPN (Fuzzy Petry Nets), RM (risk matrix), etc.

The fourth and the fifth industrial revolution have some common points but in the current geo-political situation and global dynamic, the much-needed focus on sustainability is the main difference that should be achieved [2]. Industry 4.0 is mostly centered on digitalization, artificial intelligence, cyber-physical systems, productivity increase, and cost reductions without a complete understanding of the negative foreseen or un-foreseen impact on the environment, climate, social dimension, and resources [2]. Industry 5.0, instead, is focused on creating the proper environment for sustainable development by combining technology with human-centered approaches and supervising systems for well-being, resilience, and overall

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sustainability [2], [7]. The Fourth Industrial Revolution brought about significant benefits for companies, such as productivity and performance increase, better quality, faster development and launching of products, solving the problems of staff shortage, etc. These benefits are ensured by „intelligent factories" using advanced technologies: digitalization, virtual and augmented reality, digital twins, additive manufacturing, autonomous vehicles and robots, cloud computing, big data analytics, etc. [7-9]. On the other hand, the companies that adhere to these technologies are facing problems as major changes for the operators and their results, the working area becomes more complex, the operators' skill level needs to be higher, the tasks are more intricate, the operators acquire a fear for job loss, new risks caused by human-machine and human-robot interactions, RGPD (General Data Protection Regulation) issues, cyber security problems, phishing attacks [8], [10-12], [14], thus requiring significant changes to the processes and the workforce to handle the challenges, [12-13], [15]. In robotic cells with collaborative tasks, the people and the robots work together to achieve the target job, or the maintenance employee works to perform different operations on the machines. The collaborative work environment becomes more complicated when involving intelligent systems, related to Industry 5.0, that can make decisions autonomously, because the companies will have to use advanced CAD-CAM technologies and Digital twins to monitor the safety of the processes, but the risks associated with the processes' dynamic, execution or measurement uncertainty, operator training, and machine failure grow considerably [16]. As the transition from Industry 4.0 to Industry 5.0 already demonstrates, it will require considerable foresight to develop risk assessment methods and models suitable not only for current technologies, but also with future ones [17] while integrating stricter legislation and evolving standards from health, and safety and risk management [18], as the focus on well-being increases.

This paper presents a review of the current situation concerning risk management approaches in advanced industrial models applied to the automotive industry. A conceptual framework based on specific criteria is developed to aggregate the most important aspects of these reference documents.

2. MATERIALS AND METHODS

At the beginning of the study, the research methodology was created based on good practices specific to the field of engineering management (Figure 1). The arguments presented in the introduction section form the basis of the context analysis that is further refined by means of a literature review of studies and international standards in the field of safety and risk for collaborative work environments. The Comparative analysis of the reference standards follows, based on criteria proposed by the industrial partners of the study. As a consequence, the Conceptual framework is created for using and integrating the most relevant provisions of the referential for the needs of the automotive industry when undergoing accelerated digitalization. In the final step, the framework is deployed.

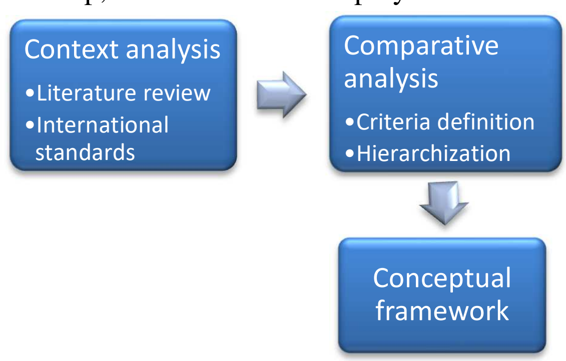

Fig. 1. Research methodology for defining a customized risk assessment approach

In the Context analysis, the literature review has been elaborated using a dual-funnel approach centered upon types of risks and risk assessment methods, respectively. The risk survey starts from general industrial risks and progresses to automotive industry-specific risks and further on to Industry 4.0&5.0 unique challenges, while the methodology component starts with universal assessment models and reaches automotive and technology-focused evaluation approaches. The focus of the work in this section has been on creating an overview of the research landscape and connecting it to the larger challenges encountered in the sector.

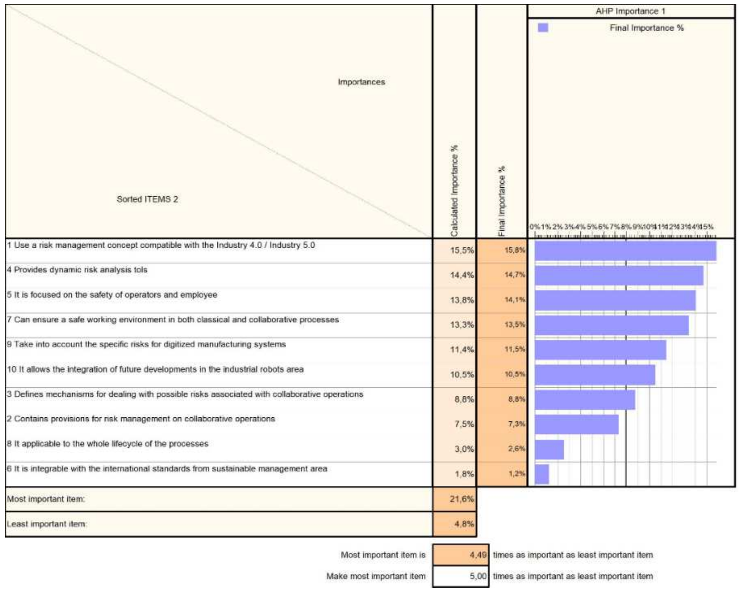

Fig. 2. Qualica AHP hierarchization of comparison criteria

For the Comparative analysis, the criteria were defined by the industrial companies that partnered with the study – 6 automotive component manufacturers from Transylvania, which were questioned using unstructured interviews based upon the description of the research methodology. This constitutes a type of delocalized brainstorming that led to 23 initial criteria that have been combined and reformulated to generate a set of 10 workable items for the study (Table 1).

Table 1

List of criteria for comparing safety / risk standards

No.	Criterion
1	Use a risk management concept compatible with the Industry 4.0 / Industry 5.0.
2	Contains provisions for risk management on collaborative operations.
3	Defines mechanisms for dealing with possible risks associated with collaborative operations.
4	Provides dynamic risk analysis tools
5	It is focused on the safety of operators and employees.
6	It is integrable with the international standards from sustainable management area.
7	Can ensure a safe working environment in both classical and collaborative processes.
8	It applicable to the whole lifecycle of the processes.
9	Take into account the specific risks for digitized manufacturing systems.
10	It allows the integration of future developments in the industrial robots' area.

The criteria presented in Table 1 are usable within the intended analysis after they are ranked through pair-wise comparison, as external references are not possible in this case.

The hierarchization was performed using the AHP (Analytic Hierarchy Process) method from the Qualica QFD software tool, and the results of the process are shown in Figure 2. As can be seen, the most important criterion is "Use a risk management concept compatible with the Industry 4.0 / Industry 5.0", with a resulting importance weight of 15,5%, followed closely by "Provides dynamic risk analysis tools", with a percentage of 14,4% importance in the criteria set, "It is focused on the safety of operators and employees" with 13,8% and "Can ensure a safe working environment in both classical and collaborative processes" with a weight of 13,3%. The least important criteria are: "It is integrable with the international standards from sustainable management area" with a resulting percentage of 1,8% and "It is applicable to the whole lifecycle of the processes" with 3% importance. Further on, these weights are normalized by the application to a 5x difference between the most and least important items, but in this case, it was not necessary to apply this operation since the resulting difference is 4,49x, which is already very close to the standard.

A list of ten international standards from ISO used for industrial risk assessment and linked to the collaborative operations in collaborative works environments was defined and is listed in Table 2. The selection was further verified for relevance and accuracy with the aforementioned industrial companies that have lent their support and expertise to the study. The list itself is extendable with more similar items, although the probability of obtaining different results during the next stages of implementing the research methodology is rather low, as the coverage degree of processes, challenges and issues specific to risk, and safety management is already a high one. The final stages of the methodology are presented in detail in the Results section and include the definition of the Conceptual Framework that observes the results of the previous analyses (Context, including literature, and Comparison, including standards). During the elaboration of the output, elements of the following techniques were implemented: mind maps, network diagrams and IDEF1 models.

Table 2

List of risk and safety in collaborative tasks linked international standards

No.	International standard
1	ISO 12100:2010 - Safety of machinery - Risk assessment and risk reduction
2	ISO 10218-2:2011 - Part 1: Robots
3	ISO/TS 15066:2016 - Robots and robotic devices - Collaborative robots
4	ISO 45001:2018 - Occupational health and safety management systems
5	ISO 31000:2018 - Risk management - Guidelines
6	IEC 31010:2019 - Risk management - Risk assessment techniques
7	ISO 6385:2016 - Ergonomics principles in the design of work systems
8	ISO/TR 14121-2:2012 - Part 2: Practical guidance and examples of methods
9	ISO 14121-1:2007 - Safety of the Machinery - Risk assessment: Principles
10	ISO 10218-2:2011 - Part 2: Robot systems and integration

3. RESULTS

The aim of the study was to identify the state of the art in the risk management area with relevance towards collaborative tasks in the automotive industry. To achieve this target, a number of 39 publications from the past 5 years available on Clarivate Analytics' Web of Science have been identified and analyzed.

3.1 General industrial and automotive specific risks during digitalization

Digitalization and intelligent processes have become standard nowadays in the automotive industry because of high competition and customer requirements leading to major changes for the companies and the employees. Even if the new technologies have mostly positive effects as the product development and lead time decreased drastically, the communication in the supply chains is expedited, the process efficiency increases, the physically intensive tasks are taken by over the robots, there are also negative aspects linked to the operators' lack of knowledge, the need to adapt to the new collaborative work environments, to the increase in resource and energy use, cyberattacks, etc. [14], [19]. Industry 4.0 is highly associated with digitalization in the automotive industry, but machines and robots can have higher priority than human operators and this complicates the risk management perspective, with possible solutions within the Industry 5.0 paradigm that is focused on sustainability and human-centered [5]. These new approaches also determine paradigm changes in the storage, communication, and transmission of information, as companies have started to use Cyber-Physical Systems applications and Cloud Computing solutions that are cheaper and ensure quick access to data from anywhere, but at the same time introduce new informational security risks and current methods of risk assessment are not fully efficient in this respect [20-22]. The cyber-security aspects are already and will continue to be a major challenge for the automotive industry because the system can be attacked from inside or outside, intentionally, or unintentionally, but the current international standards applied do not integrate the needed use of dedicated technological solutions [22-23]. Currently, the mechanisms to solve cyber-security issues are provided by the international standard ISO 27001. Also, dedicated to the automotive industry, the VDA (German Association of the Automotive Industry) has developed its own instrument based on this standard, for audit and information exchange, called TISAX (Trusted Information Security Assessment Exchange), that supports companies in addressing cyber risks [20]. Collaborative tasks, especially in robotic cells, have considerable advantages for companies. From the risk management perspective, the problems were treated by re-searchers and there are available a large number of international standards, but the risk assessment and the implementation of the actions are not based on strong qualitative analyses and detailed risk descriptions. As such, there could appear injury risks due to task speed, robot forces and torque limits not well defined, reaction time of the sensors, motors, machines, and other equipment and the faulty collaborations between the operator, and the machines [24-26]. As Industry 4.0 and Industry 5.0 become commonplace the tasks become more complex, the systems more intelligent, and the machines are able to make decisions by themselves, further increasing the real and perceived risks [16], escaping for the moment the regulatory intention of the existing standards [27]. Artificial Intelligence is becoming an important part of industry nowadays and collaborative tasks are gaining popularity in the automotive industry with the support of Machine Learning and Autonomous Machines (process machines, robots, transportation vehicles, and the cars themselves) [28]. These technologies are based on software development and dynamic systems that can make decisions based on the situations and environment encountered. Operator safety is thus a major concern because human operators can have unpredictable behaviors and the traditional risk management systems are not able to handle properly the interaction risks. One possible solution to this conundrum would be to make real-time simulations and data collection (using, for example, Digital Twins) but this still cannot guarantee complete efficiency [28]. The pandemic situation, and the subsequent economic crises, as well as the semi-conductor shortage, natural disasters, terrorism, and other unwarranted events from the past years also revealed new kinds of risks that have influenced the overall business sector [29]. A basic solution would be the introduction of voluntary redundances, to increase flexibility and reduce the threat level, but not every time it is possible to implement this, due to costs. A more complex solution would be to use Big Data Analytics solutions to simulate, analyze, and identify improvement actions for the complex supply systems behavior, but this can also induce new operational or cybersecurity risks [29-32]. Due to its overarching implications, Artificial Intelligence and Collaborative Robots bring about economic risks too, such as job loss for the operators, difficulty in finding new jobs for the operators replaced by the machines, costs with medical leaves and physical injuries, up to anxiety, and other psychological problems [33]. However, the fifth industrial revolution can solve a part of these aspects due to the focus on sustainability and well-being [5].

3.2. Risk management instruments and methods

FMEA (Failure Modes and Effects Analysis) is one of the most common instruments used in risk management in the automotive industry, with the aim of preventive identification of the possible defect modes and their effects, risk assessment and quantification, and the improvement of the product and processes to achieve design conformity, safety, and reliability [34-35]. FMEA is using the RPN (Risk Priority Number) indicator as a base instrument for estimating and prioritizing risk, taking into account three assessment directions: occurrence, detection, and severity and prompting decisions based on their level and arithmetic multiplication, with many variations being proposed all the time since the method's introduction [34-35]. An improved extension of FMEA is the FMECA (Failure Mode, Effects, and Criticality Analysis), which has the same base as the FMEA and the RPN and usually is combined with other instruments in the area of multi-criterial decision-making for a higher effectiveness [36]. Based on the literature review, some models based on FMEA and FMCEA, developed by different authors have been identified with the potential to be used for collaborative and digitalized work environments. Lo & Liou [34] have developed an FMEA model combined with BWM (Best Worst Method), GRA (Gray Relational Analysis), and interval analysis. La Fata et al. [36] advance a model based on FMCEA but for better accuracy, it is combined with the ELECTRE TRI (Elimination et Choice Translating Reality) technique. Wang et al. [37] propose an FMEA-based model that combines the RPN value and apply the Google-made-famous PageRank algorithm that takes into account supplementary augmentation and attenuation influences in the evaluation process [37]. SCEA (Safety and Critical Effect Analysis) uses almost the same methodology as FMEA but is multiplying four risk factors - Probability, Severity, Frequency, and Detectability on a different scale, with different meanings for each value [6]. Bayesian Networks (BN) are widely used for risk assessment providing the benefit of both graphical and mathematical modeling at the same time and serving as support for qualitative and quantitative interpretations [38]. Fuzzy set theory and Petri nets can effectively handle subjective data, incomplete data, fuzzy data, and hard-to-quantify data and it was adopted in many areas of risk management, combined by some authors with FMEA - for incertitude facing, or HAZOP (Hazard and Operability Analysis) - for hazard estimation and analysis [39]. The analysis is based on a large knowledge database from the professional area, obtained from experts that belong to different domains, [40]. The researchers have developed fuzzy models such as fuzzy Amdani, fuzzy Takagi-Sugeno, fuzzy production rules, and Petri Nets-based models, but the most popular of them is the combined Fuzzy and Petri Nets model, which is a dynamic instrument that provides significant advantages, by using an easy-to-understand graphical representation of the complex causal relations between the events [39-40]. Zhou & Reniers have developed a model called WFPN (Weighted fuzzy Petri nets) [39], while Wang et al. [40] have proposed the model SFPN (Synergy-effect-incorporated fuzzy Petri nets), further expanding the capabilities of the original models. Fault Tree Analysis is a risk instrument that applies a hierarchical approach, from possible upper-level defects to intermediate and basic defects, modeling the dependencies between them using "AND", and "OR" type logic gates [41]. Mahmood et al. propose in [42] an FTA model-based, called Fuzzy Fault Tree Analysis (FFTA) with expanded rotational fuzzy sets that combine the values of appearance probability with the uncertainty estimations [42]. These standards provide methodologies, advice, instruments, and models for risk assessment and risk mitigation in different domains and also use already defined and well-known instruments as the ones mentioned before. ISO 45001:2018 - „Occupational health and safety management systems", provides general guidance and requirements for developing and maintaining an occupational safety and health management system in the organization [43]. ISO 12100:2010 „Safety of machinery - General principles for design - Risk assessment and risk reduction", clarifies the main terminology, the preferred risk assessment, and risk mitigation methodology, and principles for equipment design and operation, based on knowledge, recorded incidents and injuries caused by machinery [44]. ISO 10218-1:2011 - „Robots and robotic devices Robots and robotic devices - Safety requirements for industrial robots - Part 1: Robots" and ISO 10218-2:2011- „Robots and robotic devices Part 2: Robot systems and integration", are fostering the application of risk tools to the robotic cells with industrial robots and automatic production lines [45-46]. ISO/TS 15066:2016 - "Robots and robotic devices - Collaborative robots" provides guidance and tools for safety design, risk assessment, and risk mitigation for collaborative robotic systems, it is complementary to ISO 10218-1:2011 and it is applicable for robotic lines as described in ISO 10218-1:2011 and 10218-2:2011 [47-48]. The main collaborative operations safety measures are described in the standard (safety stop, manual guidance, speed monitorization, and protection systems, torque and force limitation) [49]. ISO 31000:2018 - „ Risk management", represents a detailed reference that is providing to the top management general information for risk management, planning, implementing corrective and preventive actions and lesson learned, but requires expert knowledge to implement [50]. The COSO (Committee of Sponsoring Organizations of the Treadway Commission) ERM (Enterprise Risk

Management) is a private initiative that provides examples based on ISO 31000:2018 [51].

3.3. Conceptual framework development

The initial results of the AHP ranking are used as input criteria for the Pugh Concept Selection method applied with the help of the Qualica QFD software to the 10 preselected relevant standards in the field of risk and safety management for collaborative tasks. The process is presented in Figure 3 below. The results of the matrix calculations performed with the Pugh method are based on the interviews with the 6 collaborating companies and reveal three levels of correlation: useful standards (positive impact close to or above 25%), neutral standards (impact around 0%) and conflicting standards (negative impact). As can be seen, the most relevant standards and tools are given by ISO 10218-2:2011 - "Robots and robotic devices - Safety requirements for industrial robots - Part 2: Robot systems and integration" with a net effect of 8 points and a final net effect of 43,6%. This is followed closely by ISO/TS 15066:2016 - "Robots and robotic devices - Collaborative robots" with a net effect of 7 points and a final net effect of 38,8%. Positive effects are also recorded for the standard EN ISO 12100:2010 - "Safety of machinery - General principles for design - Risk assessment and risk reduction ", with a net effect of 6 points and a final net effect of 29,4%, ISO 10218-2:2011 - Robots and robotic devices Part 2: Robot systems and integration with a net effect of 6 points and a final net effect of 25,3%, and ISO/TR 14121-2:2012 Safety of machinery - Risk assessment - Part 2: Practical guidance and examples of methods" with a net effect of 7 points and a final net effect of 24,3%. The more problematic standards are ISO 6385:2016 - "Ergonomics principles in the design of work systems" with a net effect of -2 points and a final net effect of -24,7% and ISO 45001:2018 - "Occupational health and safety management systems" with a net effect of -3 points and a final net effect of -21,4%. At the same time, 3 standards fall in the neutral zone, with 2,1% and 2,0% net effect: ISO 31000:2018 - "Risk management – Guidelines", IEC 31010:2019 - "Risk management - Risk assessment techniques", and ISO 14121-1:2007 - "Safety of the Machinery - Risk assessment: Principles", respectively. By critically analyzing these results, we come to the conclusion that ISO 10218:2011 is in the best position to cover the most important aspects related to collaborative tasks in the automotive industry under the Industry 4.0 and 5.0 paradigms. The other 4 standards in the positive impact category do not overtake it for any criteria, so their addition would not necessarily yield better results for the companies. On the other hand, since this is a technically specific standard, it should be complemented by a general one and the largest scope is found in the neutral standards category with ISO 31000:2018. However, all the standards, including the two preselected above, correlate negatively with the core tenets of the two industrial models, so their supplementation with specific know-how is mandatory. Basically, the framework to be used in the testing phase to follow includes the implementation of ISO 31000 at company level, the use of ISO 10218 at process level and the specific modulation of the risk assessment in line with Industry 4.0 and 5.0: digitalization, virtualization, systems integration, connectivity and autonomy, sustainability, and humanness.

4. CONCLUSIONS

The literature survey and the standards' analysis show that instruments and risk management and risk mitigation models are available for different phases of the process and product lifecycle, starting from development and until commissioning, but they tend to lack a connection with current industrial challenges and transformations and fail to take into account the increasing intricacy of interactions between humans and machines on a factory floor [8]. The intelligent factory concept is still an ideal concept for many companies and the ones who make the important steps to Industry 4.0 and Industry 5.0 are implementing it only partially and are facing major challenges in all the areas that demonstrate complex dynamic capabilities [9], [11]. Risk management, especially considering the involvement of the human factor, qualifies in this area, as it is influenced by a multitude of external factors, from legislation to psychological aspects.

CRITERIA \ STANDARDS	1 EN ISO 12100:2010 - Safety of machinery — General principles for design — Risk assessment and risk reduction	2 ISO 10218-1:2018 Robots and robotic devices — Safety requirements for industrial robots — Part 1: Robots	3 ISO/TS 15066:2016 - Robots and robotic devices - Collaborative robots	4 ISO 45001:2018 - Occupational health and safety management systems	5 ISO 31000:2018 - Risk management - Guidelines	6 IEC 31010:2019 - Risk management - Risk assessment techniques	7 ISO 6385:2016 - Ergonomics principles in the design of work systems	8 ISO/TR 14121-2:2012 Safety of machinery — Risk assessment — Part 2: Practical guidance and examples of methods	9 ISO 14121-1:2007 - Safety of the Machinery - Risk assessment: Principles	10 ISO 10218-2:2011 Robots and robotic devices — Safety requirements for industrial robots — Part 2: Robot systems and integration	Importance
1 Use a risk management concept compatible with the Industry 4.0 / Industry 5.0	--	--	--	--	--	--	--	--	--	--	15,5%
2 Provide dynamic risk analysis tools	O	O	O	-	+	+	-	+	-	+	14,4%
3 It is focused on the safety of operators and employee	++	++	++	++	++	++	+	++	++	++	13,8%
4 Can ensure a safe working environment in both classical and collaborative processes	++	++	++	O	+	+	+	+	+	++	13,3%
5 Take into account the specific risks for digitized manufacturing systems	+	+	+	O	O	O	O	+	O	+	11,4%
6 It allows the integration of future developments in the industrial robots area	O	+	+	--	-	-	-	O	O	+	10,5%
7 Defines mechanisms for dealing with possible risks associated with collaborative operations	+	+	++	-	O	O	O	++	O	++	8,8%
8 Contains provisions for risk management on collaborative operations	++	+	++	-	-	-	--	+	+	++	7,5%
9 It applicable to the whole lifecycle of the processes	++	+	++	+	O	O	--	+	+	++	3,0%
10 It is integrable with the international standards from sustainable management area	+	O	+	O	+	+	+	+	+	+	1,8%
Positive Effects	7	7	8	2	4	4	3	8	5	9	
Negative Effects	1	1	1	5	3	3	5	1	2	1	
Neutral Effects	2	2	1	3	3	3	2	1	3	0	
Net Effect	6	6	7	-3	1	1	-2	7	3	8	
Positive Priorization	44,9%	40,8%	54,3%	14,8%	23,6%	23,6%	9,6%	39,8%	22,3%	59,1%	
Negative Priorization	-15,5%	-15,5%	-15,5%	-36,3%	-21,5%	-21,5%	-34,3%	-15,5%	-20,3%	-15,5%	
Net Effect	29,4%	25,3%	38,8%	-21,4%	2,1%	2,1%	-24,7%	24,3%	2,0%	43,6%	

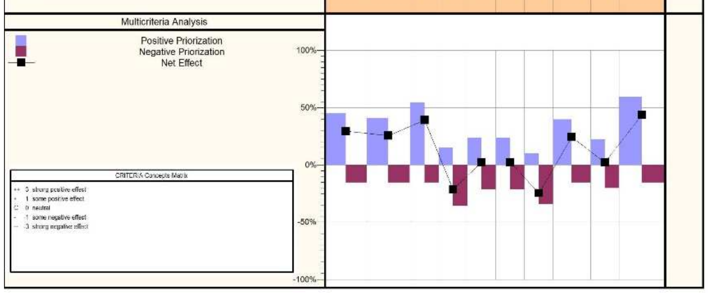

Fig. 3. Qualica Pugh-based comparison of risk related standards

To solve these issues, some solutions are proposed by different authors: wearing sensors by the operators to supervise their behavior and movements in collaborative operations, hazard prediction by the equipment based on machine learning of human behavior, systems used to detect if the operator is tired, especially for high risk and dangerous processes, emotion evaluation, dynamic scheduling and analysis, digital twins technology, augmented reality, virtual reality, multicriterial management decisions, taking into account social responsibility and sustainability aspects [52-55], but at the same time, the operator and the employer should evolve and align to the new concepts, or other-wise bear the costs of inefficiency [15]. The current employees won't adapt so easily to the new technologies and to their safety problems because of natural resistance to change, missing competencies and skills, conservative attitudes, inadequate school system, and the adaptation process can be long and difficult [15]. At this moment, the literature shows a lack of maturity in approaching human-centric aspects, ergonomic factors, social responsibility, and sustainability, as most of the publications about Industry 4.0 are focused on the technical problems that can occur but not on the risk management issues, and the ones which are treating the human and ergonomic factors are mostly devoted to the conceptual problems, simulations, and experiments [9], [11]. Based on the documented evolution of the operators' and management roles, it is apparent the need to develop similar safety concepts, which will ensure the proper safety frame in the companies by integrating all the stakeholders in a sustainability-minded framework, and by stimulating the employees to become more involved and creative, and to propose improvement ideas by receiving adequate training [15], [53], [55]. Another important factor to consider in new technologies implementation is represented by the legislation in the safety and security area, which should be updated and will have to be able to provide technologically savvy risk assessment and mitigation instruments [18]. Most of the current risk management models have a classical linear thinking behind them, unresponsive to dynamic and ambiguous situations. The current risk management approaches are not able to deal, at this time, with the related Industry 4.0 and Industry 5.0 new risks, and new models and regulations must be developed soon, otherwise the hazards and injuries will increase, and the safety of the operators and the process will decrease. Based on the literature review and comparative analysis of existing standards, the current research proposes a conceptual framework that combines existing references and as-yet-undefined materialization of industrial principles into a generic risk management model, applicable at all layers, that takes into account the emergent technologies from the automotive industry, as the ones introduced by Industry 4.0 and Industry 5.0. A complete approach should be able to integrate innovative solutions such as artificial intelligence, brain control, digital twins, and others, as they become more prevalent.

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Analiza literaturii de specialitate privind evaluarea riscurilor de siguranță în medii colaborative

Rezumat: Prezenta lucrare abordează problema evaluării riscurilor în mediile de lucru colaborative, din industria auto, specific celei de a patra revoluții industriale, unde roboții și operatorii lucrează împreună. Metodologia cercetării conține o analiză a literaturii de specialitate, combinată cu o analiză comparativă a standardelor de referință pe baza interviurilor cu partenerii din industrie. Ierarhizarea criteriilor s-a realizat utilizând metoda AHP iar pentru dezvoltarea cadrului conceptual s-a folosit metoda Pugh de selecție de concept din cadrul softului Qualica. Studiul concluzionează faptul că modelele actuale pot fi combinate și extinse pe baza noilor principii industriale, dar aceasta este o soluție pe termen scurt, întrucât provocările celei de a cincea revoluții industriale vor deveni în curând realitate.

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