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OCCUPATIONAL SAFETY MODELLING

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SUMMARY: The traditional theory of occupational safety has played an important role in promoting the development of occupational safety. Its use effectively reduced the number of casualties and saved thousands of lives. However, it turned out that the "margin effect" has become more and more obvious. World statistics show that the number of accidents at the workplace has dropped to a certain level and can no longer be reduced to zero. This means that it is necessary to search for new methods in theory that would help reduce the number of accidents. A review of recent articles in this field shows us new trends in the development of safety and safety at work. The Chinese study looked at the benefits of the Job Safety Analysis (JSA) in the construction industry. Safety-Related Data (SRDs) are important factors for making Safety Decision-Making (SDM) in a company. A systematic approach to risk assessment in the field of occupational safety and health is linked to a new process for identifying risk factors together with weighing the influence of these risk factors. For the weight of the factors in adverse events, a multi-criteria model is used to analyze the analytical hierarchy. Using appropriate Big Data processing, we can achieve more efficient forecasting of crisis events that lead to accidents at work.

Key words: *working environment, models, safety*

INTRODUCTION

Industry 4.0 (abbreviation I 4.0) is often called the Fourth Industrial Revolution. In the fourth industrial revolution, smart grids are the ones that will bring about fundamental change. It represents a huge potential for greater flexibility and profitability of the industry, strengthening the competitiveness of the economy, for new jobs and a high standard of living. Industry 4.0 is a common term for technologies and concepts to regulate the entire value chain. This industry is a revolution in manufacturing and brings industry a new perspective on how manufacturing can be obtained with new technologies to achieve maximum production with minimum use of resources. Industry 4.0 is a German project that combined manufacturing with information technology *(Adolph et al., 2016)*. The result of this collaboration is the development of factories that are "smart," meaning that they are very resource efficient and adapt very quickly to management goals and current industrial scenarios *(Yalmaz, Tüfekci, 2018)*. The information technology part of Industry 4.0 consists of a cybernetic system (CPS), cloud computing, and the Internet of Things (IoT). Due to the CPS, the whole plant is quickly adaptable *(Wang et al., 2019)*. It is a system shaped by the integration of physical systems; in the case of production, these are machines such as CNC, lathe, etc.

Most of the studies reviewed focused on the development of theories listing the advantages and limitations of Industry 4.0. However, current

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research trends focus on investigating the relationships of factors influencing the performance of Industry 4.0. Further studies on the successful implementation of Industry 4.0 in different industrial environments are needed to improve understanding of these factors. Improved understanding will make it possible to provide guidelines for the successful implementation of new technologies according to the specific characteristics and requirements of the industry. However, it will allow companies to think before introducing new technologies *(Oesterreichand Teuteberg, 2016)*. Multicriteria decision-making techniques such as interpretive structural modeling (ISM) and analytical hierarchical process (AHP) can be used to develop these relationships.

Lean manufacturing has played a key role in mass production systems focused on improving product quality in order to satisfy customers. Industry 4.0 and lean manufacturing approaches can be mutually supportive *(Mrugalska and Wyrwicka, 2017)*. The reviews highlight various Industry 4.0 technologies that increase the combining power of organizational improvements, or adjustments to the development of these new technologies that need to be analyzed for their impact on lean manufacturing *(Mrugalska and Wyrwicka, 2017)*. Studies need to be carried out on the practical application of lean manufacturing implementation in smart manufacturing systems. In this regard, various security problems arise that can be solved with new models based on mathematical and physical models.

METHODS

A review of the literature is an essential part of any research work. Assessing and analyzing the relevant literature allows us to identify potential research gaps. By reviewing this literature, we achieve the strengthening of the field of study *(Tranfield et al., 2003)*. Saunders and colleagues *(2016)* prescribed a structured literature review with an iterative cycle of identifying relevant keywords in the search for relevant literature and performing analysis at the end. In this paper, the authors have adopted a similar review procedure. For research on new security trends *(Kamblea et al., 2018)*, relevant sources of publications on industry 4.0 and smart manufacturing developments were first identified. For this, the authors referred to articles from the Web of Science (WoS) database, which contains a large number of acclaimed publications such as Emerald, Taylor and Francis, Springer, IEEE and Elsevier. Through resource analysis and inductive reasoning, we try to find guidelines for safety science development trends.

RESULTS

Dynamic entropy safety model

Traditional safety analysis uses the method of qualitative analysis from occupational safety theories. Multi-year accident monitoring through safety analysis shows that this analysis does not give adequate effects. It is very difficult to find the rules of events that lead to an accident, especially if we consider a small number of similar events. According to the traditional theory of occupational safety, the accident can be attributed to dangerous human factors, dangerous condition of equipment, dangerous environmental factors and inadequate management of occupational safety, etc. For example, road traffic, some drivers drive a certain route safely and other drivers experience an accident on the same route at the same time. We assume that the accident was caused by the driver's behavior, for example due to speeding. Although the car is operating normally, it will cause an accident due to rainy weather or driver fatigue, or due to an improper reaction resulting from the current incoherence. These seemingly scientific rules are actually based on insights from an accident analysis. This, in turn, means that there are still many unknown causes leading to the incident.

Wu and Li *(2019)* tried to avoid problems with a new theory. With the help of data statistics and analysis of events that lead or do not lead to an incident, we can determine more precise rules that lead to an accident. When the analyzed sample is large enough, it provides us with sufficiently reliable results. Therefore, with qualitative analysis, we use deductive methods based on the idea that a general event is successful (without an accident) against a specific - incident event. The entropy law from physics is used on the solution model.

The theory of success of safety at work using entropy is proposed, which establishes a dynamic model of safety entropy.

Based on the theory of success in the field of occupational safety, a construct of the occupational safety system is proposed. To facilitate the study, we divide the system into four modules:

- human,
- material,
- environment and
- management.

Thus, the system is divided into a study of each module. For each module, according to the success theory of occupational safety, we want to master the dynamic information in the process development. In order to improve the use of module accuracy, we also want to know the basic information about the module. We try to gather all possible events about the success of the system. In doing so, we can use data mining or other technology in which we find rules and characteristics that maintain a normal state. With this realization, we can suggest measures to control the system. Through the analysis of each module and the use of technology for the normalized state of the entire system, we also achieve the security goal.

The number of events triggered by people's daily lives is very large. If we can start research from success events, and study the development of success events and rules, then we will comprehensively and accurately grasp the development trend of events and finally solve the problem of safety at work. It is proposed that the theory of occupational safety success be based on the study of the dynamic process of the system as a means of applying an appropriate method to investigate the rules and characteristics of the system. Here we define a system as an independent unit of general events, which is an organic whole of one or more components. We separate the basic and dynamic data of an individual module, which are obtained by one of the data collection methods. Because there is too much data, we use computer methods of mining and analysis. So we get the data system as we see in Figure 1 *(Wua et al., 2019)*.

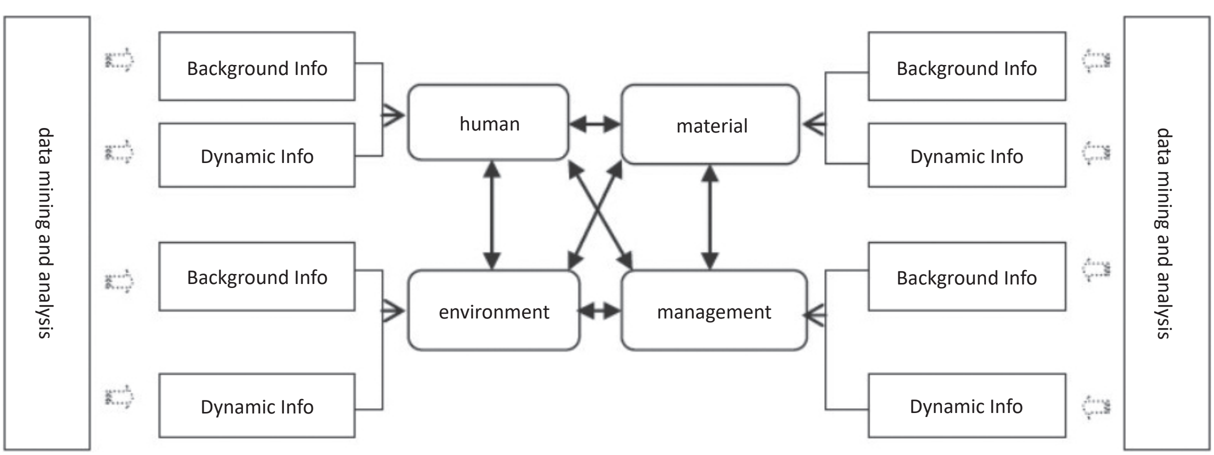

Figure 1. Form of the system of success theory of safety at work
Slika 1. Oblik teorije uspješnosti zaštite na radu

We imagine the model as a dynamic physical system. The second law of physical thermodynamics states that the entropy of an isolated system increases until equilibrium is reached *(Denbigh, 1985, Grandy, 2008)*. Physical theory is used in the safety system. The level of danger in such a system represents entropy. According to the law of thermodynamics, therefore, in an isolated system where there is no external influence, the entropy of the system increases until it reaches a maximum. From a macro point of view, at this point the system is likely to cause an accident. We will prevent this by introducing energy into the system that maintains entropy. Even in the case of excessive energy intake, system disturbance (entropy) can be reduced and the level of system security can be improved. This explains why we emphasize the need to improve occupational safety management, occupational safety training and inputs for occupational safety. These are the input data of external energy to the system, adding energy to the system to reduce disturbance that is to reduce the entropy of the system.

In traditional occupational safety, we see that measures to prevent incidents or accidents relate to the time of adding energy to the system (current implementation of the measure). This will reduce the entropy of the system (dangerous disturbance) in a short time, but the disturbance (entropy) will start to change again. Therefore, it is necessary to regularly implement measures, constantly adding energy to the dynamic system. (Example: Training employees for safe work cannot be a one-time measure.) A one-time addition of energy does not meet the needs of a regulated system that does not change in the long run and its essence is to reduce the initial entropy to a certain level. Any omission of adding energy (measures) to a system causes an increase in entropy in that system. The model proves to us the need to constantly add - improve risk reduction measures.

Use of data-driven safety decisions

How to make an effective safety decision is always an interesting safety management issue. Safety-Related Data (SRD) is the most valuable tool for making safety decisions in organizations (SDM), especially in today's era of large amounts of data. Researchers focus on the impact of the potential values of SRD for SDM decisions and seek to systematically answer some fundamental questions concerning the new SDM paradigm, known as data SDM, from a theoretical point of view. These issues are examined from the following aspects:

(1) what is it,
(2) what are its benefits,
(3) what are its theoretical foundations,
(4) what basic elements it consists of,
(5) what factors affect it, and
(6) how the organization should implement it and implement smart security management through its use.

Other theoretical and practical contributions include:

- discussion of the problems of traditional SDM approaches and how to solve them, justification for creation
- and the study of SDM data and proposals for future research. The article *(Wang et al., 2019)* is the first to examine the specific issues of data SDM, so its results have important implications for the future of research and practice in the field of data SDM and smart security management.
- Data scientists convince us that we are "completely data" so completely dependent on the data we collect. This can be disputed, and there is no doubt that the concept of 'data-driven' can play an increasingly important role in SDM.

In recent years, the Occupational Safety and Health Services have begun to closely monitor the SRD data included in the collection of data on the production process. More and more researchers and security management practitioners are realizing that SRD plays an important role in security and is a valuable tool for security management, especially when it comes to big data. In addition, the data impact on SDM is seen as a new and effective challenge to address the safety issues facing traditional occupational safety and health. However, it is not enough to consider data-based SDM as the greatest option for SDM and smart security management. There is a strong lack of supporting theory that guides the implementation of SDM in the area of safe management. In other words, although data-driven SDM has gradually alerted researchers to safe management, an in-depth theoretical study on data-driven SDM is not yet available. There are still many unanswered basic questions about SDM based on data. The article *(Wang et al., 2019)* was intended to systematically answer some basic SDM questions based on data, from a theoretical perspective, to provide a solid theoretical basis for future research and practice of data SDM. Key directions for future data-based SDM research are proposed. Clearly, data-based SDM is a new approach that uses high-quality SRDs to support, guide, and improve SDM and achieve smart security management in the information age, especially in the big data age. Therefore, data-based SDM is a popular topic and will continue to be so in the future. The study *(Wang et al., 2019)* is the first work to examine the basic issues of a specific data SDM. The results of this study are important implications for the study and implementation of SDM data.

Changes in the working environment

The way of employment in the EU has changed dramatically over the last ten years. Other forms of work have grown: part-time employment, work from home, agency work, fixed-term work, contract work. (A common term for most of these works is precarious work.) New forms of work are also changing the work environment. "Changing or a new work environment" is a broad term that encompasses new trends in the work environment. The changing work environment is becoming more common, so they looked for terminology and a description of new trends in the literature, European and international reports, European studies and the European Commission's Green Paper and communications. New trends in the work environment are caused by new organizational forms of work, new contractual relationships.

Koukoulaki *(2010)* briefly presented new trends in the work environment, including new organizational forms of work, new contractual relationships, new technologies and changes in the workforce. This document presents existing evidence on the effects of a changing work environment on safety and accidents at work. In addition, a basic mechanism is proposed to explain the effects of organizational factors. Challenges to prevent threats to policy makers are also addressed. Finally, a sustainable system of work is proposed as an alternative to intensive systems. There is growing evidence that a new work environment can have a negative impact on safety. The reduction in the number of employees was related to the reduction in safety results, where lean industries are more likely to have higher injury rates. Atypical workers are more prone to accidents at work. Existing data also point to a higher accident rate for migrant workers. However, further research will also be needed on specific aspects of changing the work environment and its effects on safety.

There is no evidence yet that the new work environment would lead to a deterioration in safety. Koukoulaki *(2010)* believes that a mechanism based on intensifying work and reducing resources can lead to a deterioration in safety procedures and a reduction in safety. The link between job change and poor performance has yet to be tested in future studies. With the new findings, greater security will be able to be established. Obviously, with the new work environments, the ways of preventing accidents at work will also change. The EU policies presented by Koukulaki *(2010)* in their article are intended to strengthen regulation, promote certification systems and improve training. While these new approaches may help, they are fragmented and cannot solve the whole safety problem. Organizations play a key role in avoiding the negative relationship between new trends and safety. The intensity of work as a mechanism is expected to result in negative effects. To alleviate these effects, alternative systems that are more compatible with humans should be promoted. Such systems are defined in the literature as "sustainable". The concept of sustainable systems is borrowed from ecology. Labor intensity refers to the consumption of human resources in work organizations, and the concept of sustainable work represents a vision of future competing organizations in which human resources are renewed and allow growth *(Docherty et al., 2002)*. According to the approach of structural theory *(Giddens, 1984)*, intensity is essentially due to the inadequacy or imbalance of high demands and regulations of work on the one hand and inadequately developed rules and means in collective action on the other. In order to achieve the characteristics of sustainable work systems, a new balance of reasonable requirements and available resources needs to be found by reshaping work at a higher level *(Docherty et al., 2002)*.

Multiple strategies can lead to sustainable systems. Group-based self-organization seems to be the foundation of a more sustainable system of work. The most important aspect of group self-organization is not autonomy in the classical sense, but the prevalence of resources available to groups. The groups should establish new group-oriented working rules (mutual support or decision-making). Another important aspect of sustainability in the organization of group work is democratic procedures, for example for the election of a group speaker. Last but not least, a key parameter of a more sustainable work organization is the question of how workloads are determined, the number of employees and other goals or levels. The new system gives this power directly to the group *(Docherty et al., 2002)*. The new paradigm of organizations for sustainable work is not easy to follow. In addition, practical examples of companies using such models are rare. Therefore, they do not provide insight into existing barriers against them. On the other hand, the development of sustainable work systems is a logical part of the European debate on the forms of work of the organization, as expressed in the 1997 EU Green Paper on "Partnership for a New Work Organization". This European vision of 'competitiveness and sustainable growth through resource reproduction' could be offered in contrast to the American and Japanese experience *(Eijnatten, 2000)*.

DISCUSSION

Monitoring the security situation in a company is increasingly associated with mathematical models that try to link input data from the production process in a broader sense with the security situation and the results it causes. This way of thinking and acting is becoming even more important due to the collection of all possible production data. We often borrow modeling from other disciplines and sciences. The example in the first chapter shows that it is quite possible to define the concepts of security with a closed physical model where the entropy law applies. If we know how to extract safety-related data from the collected data on the production process, we can influence safety decisions by appropriate data processing. I have talked about this several times in connection with Lisrel analysis, big data processing, and structural models.

In Europe and in the consultation, more and more new ways of employment are emerging, resulting in a different working environment than we have known so far. Of course, the new work environment also brings new dangers. This is often a completely different organization of work (lean production with high work intensity, work from home, part-time work, employment through agencies, employment through SP (independent entrepreneur) and other contract employment. All this is a great challenge for the profession and security science and health and process safety.

CONCLUSION

New technologies and new work organizations bring new risks that we did not know and we were not able to limit with the current level of knowledge. This forces us into research to better understand the problems. Every new theory in safety does not mean a qualitative leap in thinking about safer and healthier work. However, stringing together such theories and connecting them leads to a better understanding of security. That is why it is important that we take new steps towards safer work. The multitude of new steps, which may be unsuccessful in their own right, always triggers a qualitative leap towards some new knowledge.

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MODELIRANJE SIGURNOSTI NA RADU

SAŽETAK: Tradicionalna teorija zaštite na radu imala je važnu ulogu u promicanju razvoja zaštite na radu. Njegova uporaba učinkovito je smanjila broj stradalih i spasila tisuće života. Međutim, pokazalo se da je "efekt marže" postajao sve očitiji. Svjetska statistika pokazuje da je broj nesreća na radnom mjestu pao na određenu razinu i da se više ne može svesti na nulu. To znači da je potrebno u teoriji tražiti nove metode koje bi pomogle smanjiti broj nesreća. Pregled najnovijih članaka s ovog područja pokazuje nove trendove u razvoju zaštite na radu. Kinesko istraživanje proučavalo je blagodati Analize sigurnosti na radu (JSA) u građevinskoj industriji. Podaci povezani sa sigurnošću (SRD) važni su čimbenici za donošenje sigurnosnih odluka (SDM) u tvrtki. Sustavni pristup procjeni rizika u području zaštite na radu povezan je s novim postupkom utvrđivanja čimbenika rizika zajedno s mjerenjem utjecaja tih čimbenika. Za težinu čimbenika u štetnim događajima koristi se višekriterijski model za analizu analitičke hijerarhije. Korištenjem odgovarajuće obrade velikih podataka može se postići učinkovitije predviđanje kriznih događaja koji dovode do nesreća na radu.

Ključne riječi: *radno okruženje, modeli, sigurnost*

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