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PROPOSAL OF THE RISK ASSESSMENT MODEL OF VEHICLE CONSTRUCTION SYSTEMS' SAFETY UNDER THE CONDITIONS OF INDUSTRY 4.0

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Abstract

With the introduction of the concept of the industry 4.0, automation, robotics, artificial intelligence, communication methods, automotive engineering, mechanics, construction and operation of automotive vehicles, and so on, as well as the methods of corporate management are changing. Following this concept, new risks emerge, when workers have to cooperate with collaborative robots, autonomous systems, artificial intelligence, machine learning and learn new methods different from previous processes and systems. The paper first presents the theoretical background related to the topic addressed. The next sections encompass the literature review, including a list of references relevant to achieving the main objective of the paper, as well as a description of the research methods used in the paper. With regard to the main objective, quantitative research concerning the vehicle construction systems' safety issues in industry 4.0 was conducted; i.e., a questionnaire survey was developed within a sufficiently representative sample of respondents. After conducting the survey, the risk assessment model of vehicle construction systems' safety under the conditions of Industry 4.0 was proposed while applying the principles of system dynamics. An integral part of the paper is represented by the discussion of the obtained results and benefits, as well as the formulation of relevant conclusions.

Keywords: automotive safety; vehicle construction system; Industry 4.0; risk assessment model

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1. Introduction

Technology has been helping people relieve and do work more effectively. Progress is a propeller for humans in numerous sectors of industry. Substituting human labour by technology in the production process is logical as human performance is limited by an individual's physiology and psychology. The industry has been essentially changing in the past years. The world is currently in the fourth industrial revolution. This fourth revolution is intertwining with all the areas, and it is changing the current structure of industry. By virtue of the Industry 4.0 concept, there is a systemic use of digitalization, automation, robotization, integration, and interconnection of Industry 4.0 elements with the aim of rapid development and retention of companies' competitiveness in the domestic and international market, productive and non-productive areas with a special accent on our environment, ecological solutions and sustainability [12, 16].

Societies that are not currently equipped with advanced, progressive and eco-friendly technologies are losing a competitive advantage and are going to miss out on their opportunities to be at the forefront of transformation spreading into production sectors. The objective of the Industry 4.0 concept is to create a global interconnection of national economies. It is an optimal use of resources, an effective use of productive factors, and an increase in security. Industry 4.0, therefore, means an interconnection between machines and people. There is an increased emphasis on security based on transformative changes. It is the onset of robotization and digitalization that changes security requirements. New risks have been developing in connection with machines, automation, robotics, artificial intelligence, machine learning, communication methods, automotive engineering, construction and operation of automotive vehicles, and related systems [17].

The paper focuses on evaluating the safety of vehicle construction systems regarding to Industry 4.0. Industry 4.0 research with regard to automotive safety is an extensive science. The rate of safety is not necessarily only accident analysis. The aim of the paper is to evaluate the safety of vehicle construction systems in Industry 4.0, it uses the current methods which are applicable to Industry 4.0. Risk analysis is one of the approaches to view the safety of mechanics, construction, and operation of automotive vehicle systems in Industry 4.0 conditions. The output of the paper is to draft a proposal that can be guidance for risk evaluation of the projects aimed at Industry 4.0 from the beginning to the vehicle construction itself.

2. Literature Review and Analysis of the Current State

Developing the concept of Industry 4.0 and the digitalization of all economic and non-economic activities is accompanied by the effects on humans. The world of work is undergoing constant changes due to digitalization. It is a change of the current and the future mode of working. The widespread use of new digital and communication instruments creates more

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flexible forms of work, which are independent of fixed positions, standardized working hours, and stable organizational structures. Occupational health and safety remain an issue. How are the risks changing? Are risks going to change prevention with regard to the transformation of fundamental principles? As for this specific concept, it is necessary to begin with a new process of risk evaluation. Every company is trying to make maximal use of the advantages that Industry 4.0 brings about [2].

Safety issues and occupational health and safety are significant challenges for those who participate in creating legislation, regulations, and other legal provisions. Occupational health and safety commonly comply with local and temporal fixed logic of common work. With regard to the digitally created flexibility of working place and time the subject of work is increasingly avoiding occupational health and safety. Flexibility poses a challenge to the system of occupational health and safety. Health and safety are traditionally organized by operational documents. Therefore, it is a relevant issue for the current systems and strategies whether the system of occupational health and safety is able to face new challenges. Health and safety are currently an integral part of large international groups for whom it is especially linked to investment activities. As a result of this, innovations in this area are often the subject of monitoring by HSE (health, safety, environment) managers of these companies. Therefore, they have completely naturally come across start-up eco-systems, especially those for the purpose of developing solutions related to Industry 4.0 [14, 15].

Industry 4.0 influences HSE procedures by massive providing data. It is especially a direct implementation of sensors in a worker or a machine. The purpose of health and safety is to reduce the number of events threatening health and safety at work. Therefore, it is essential to reduce accidents and work-related illnesses in relation to the changing labour market [14]. The above-described changes offer opportunities for changing and establishing safe work. Although paid employment has been constantly changing since its creation, it is currently undergoing an extraordinary change of work. One of the main drivers is the digitization of work. Taking a view on the contemporary research of the digitization of the work environment is necessary to keep health and safety in the digitized world. Digitization enables saving and processing data much better, they are more easily accessible and clearer with the help of algorithms [22]. Digitalization promises a marked increase in productivity for societies affected. It is possible to implement new paradigms of de-centralized management and agile design of production processes, especially in the automotive sector. There is a further step following the transformation to digital data [21].

Digitalization often changes accustomed working procedures which creates new requirements for occupational health and safety. Current facilities often require higher flexibility during work with regard to the time and place where work is done [15]. What picture do the first studies of changes caused by digitalization show? A number of recent empirical data examine the process of changes and negotiations in the context of digitalization [20]. On one hand, digitalization promises the substitution of certain working procedures or at least a relief

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during fulfilling obligations, on the other hand, it enables a completely new quality of work quantification and work performance. The studies [1, 4] describe the forms of control and the way they impact the workers. The implementation itself is connected to further working tasks. The studies do not provide the whole process of health and safety management, but they provide certain guidance. Most studies agree on the fact that the implementation of digitalization into the working environment is often problematic. Managing information and securing cyberspace ought to be provided within digitization in the company that uses the items of Industry 4.0.

There have occurred numerous changes in most processes in the course of history. To what extent is it possible to use historic processes for current processes? British scientists arrived at the conclusion in their research that there have been significant changes in the presence in comparison to the changes in the past. The quality and the way of new working conditions and relations must be an important part of Industry 4.0. Occupational health and safety have a good structural opportunity to actively participate in the ongoing transformation of work. The whole area of occupational health and safety must be correctly understood and solved for this application. These new technologies especially change working and cognitive ergonomic procedures and ask many questions about emerging risks. It is important to identify new risks, which involve the change in ergonomics, but also the newly added psychological burden [19].

The area of stress was also examined, e.g., in [3, 13]. The research primarily dealt with the key areas of effects and relations influencing stress. The research showed that the intensity of work is still at a high level and the number of participants perceiving their work as stressful has also increased. The proportion of employees with room for change has slightly decreased since 2021. On the other hand, the proportion of full-time workers with long or excessively long working hours is almost stable, which relates to both disability and the increased frequency of work accidents, and decreased recreation. The same applies to shift work and weekend work. Approximately a quarter of employees are also influenced by flexible work. Every fifth employee states the reduction of the relaxation period – which is not recommended in terms of ergonomics.

At the onset of a new era, it is good to divide health and safety into three fundamental pillars:

- Safety management – performance in safety is operated by safety management. Values, procedures, and programs for achieving optimal values are set up. Setting up standards of safe behaviour is the purpose of the first pillar.
- Safety culture – it is the understanding of what influences company culture. The objective is to change the attitudes and behaviour of workers in this area. It is the adoption of a safety culture that aims at the improvement of staff behaviour, which decreases the incidence of extraordinary events.
- Safety systems – this pillar requires setting up strategies for managing risks. Safety systems are interlinked by individual items which must be united into one unit to achieve the objective.

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As mentioned above, concepts for Industry 4.0 dealing with its individual aspects, e.g. [1, 4, 14], have been already created. The research of the Federal Institute for Occupational Health and Safety, Germany, focusing on occupational health and safety has been a significant contribution [3]. Further contribution has been the research of the British Institute [5] concentrating on occupational health and safety.

The safety from the perspective of a robot and a human used in automotive was examined by the group of authors, Gualtiery et al. [10], who deal with ergonomics and the change of work in a human-robot cooperation in automotive industry. There is an issue of influence on a cooperating machine and a human. Therefore, it is important to assess the current state of safe and ergonomic robotic cells. Developing research areas beyond the current state of technology is especially interesting. This paper uses the systematic methodology of control to achieve this aim. The study by Souhalhi et al. [18] was another research examining smart production in the automotive sector. Their work focuses on the reliability, access, and safety points of production in automotive sector. This paper suggests a practical method used for defect diagnosis and system diagnosis regarding vehicle production. It is based on health indicators with the use of a neuro-fuzzy system.

Very few authors are currently dealing with searching for new risks and their evaluation in Industry 4.0. The risks emerging in this concept have not been integrated within the Czech Republic yet. Authors predominantly specialize in a specific risk in a particular area. Since most authors agree on the formation of new risks, the research of the thesis ought to focus on following the previous research and its application in industry in the Czech Republic.

3. Data and Methods

3.1. Quantitative Research

The quantitative research took place for several months in 2022 and at the beginning of 2023. The questionnaire was divided into two parts. The first part focused on Industry 4.0 and the knowledge about it in enterprises and the second part dealt with the costs of occupational safety. 1,000 enterprises from the whole Czech Republic participated in the questionnaire and it contained 29 questions. The questions were formulated in such a way that if the answer was negative, the respondent could not continue [11].

The companies from all four sectors (above all from the automotive industry) were contacted within the research, whereas the biggest representation was in the secondary and primary sectors. The biggest representation was by the small and middle-sized enterprises. Micro and large enterprises had approximately the same number of representatives. Regarding the knowledge about Industry 4.0, it was determined that most enterprises are largely or partially

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aware of this concept. The Industry 4.0 concept is regarded as safe in terms of data safety, process safety, or occupational safety by most respondents. The most of 1,000 contacted enterprises have implemented the Industry 4.0 concept in the sense of substituting partial processes or individual parts of the process. Where the Industry 4.0 concept has not been implemented, it was caused by lack of finance, but also due to lack of necessity. The third reason for failing to implement Industry 4.0 is the lack of information. The companies are not able to assess the risks of the whole process by themselves either at implementation or during the process. Further, the research took place where Industry 4.0 had been implemented to find out what activities had been substituted and what had happened with the workers affected. The largest substituted group was manual and administrative activities or document circulation. Sometimes, the whole process was substituted, at times, only its parts. Workers whose jobs had been substituted by Industry 4.0 were mostly transferred to another position. The second category involved those whose employment was terminated.

In the case of workers where the process had only been partially substituted the working activities remained unchanged or they were trained in, e.g., system controlling. In the case of enterprises where Industry 4.0 has been already in operation, the respondents agree that their processes have become more reliable, or partially more reliable. As for the incidence of accidents, there has been a decrease in working accidents in comparison to the previous situation, or there has not been recorded any difference yet. However, there were very interesting answers to question number 15, where other accidents or work-related illnesses began to appear. Workers often complain about headaches, pain in the eyes, fatigue, stress, or mental disorders, such as depression or anxiety. Question number 16 completed the standard area of occupational safety where the respondents could respond to this issue. A lot of respondents see the areas of occupational safety as the future for their employees and their priority is a healthy and safe enterprise. However, there are still many enterprises that are subject to a legislative setting, which is a fundamental framework for every entrepreneur. Their main priority is not to set higher targets in occupational safety. They often see that it is very expensive, or it is complicated for them, and it requires extra staff.

The second part of the questionnaire dealt with the costs related to the issue of occupational safety. The first question was about the composition of workers, i.e. whether the companies use the services of job agencies. Less than half use their services. They are, above all, production enterprises. The majority of job agency workers are from the Czech Republic, and the second part is workers from Ukraine. In most cases, the companies monitor the costs of occupational safety. Only 264 out of the respondents do not monitor the costs. Approximately, half of the enterprises monitoring the costs divide them into individual categories. There is a category of prevention, and most of the companies monitor the costs there, the most frequent costs category is the one within the limit of € 2000, and the next category is from € 4000 to € 20,000 a year. The category of the costs for providing a safe operation is again monitored by the majority of respondents that monitor total costs, and the sums provided are approximately the same as in the case of the previous category. The costs

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of accidents and extraordinary events are again monitored by the majority of respondents, and the costs within the limit of € 2000 a year and the costs within the limit of € 4000 a year are the largest groups. It seems to be caused by the number and severity of working accidents. The last category is the costs of fines.

The respondents agreed again that they monitor the costs. The biggest groups are the categories of the costs within the limit of € 2000 a year and then the costs within the limit of € 20,000 a year. The size of the costs is determined by the controls of governmental agencies (e.g., Regional Labor Inspectorate, sanitation, environment, firefighters, etc.) and by the identified flows, or by the costs related to work accidents when the legislation is infringed. The respondents could make a statement on the issue of occupational safety costs in this part as well. The answers were divided into two parts. The first part renders the costs related to occupational safety too high and finds the current legislative framework sufficient. They mind not being able to substantially influence the occupational safety costs within the framework of the current legislation. Their biggest expenses are the costs of training, revisions, the costs of accustoming the staff to individual operational regulations, or occupational safety instruments. It was interesting in this question that no respondent mentioned the high costs of personal protective work equipment as they relate to the fundamental legislative framework. The second part, in contrast, claims that the occupational safety costs are sufficient or even small.

There were also very interesting opinions when the respondents talked about the links between the costs and occupational safety, they realized that every financial unit provided for dealing with this issue consequently means financial savings in the case of extraordinary events, work accidents, or property damage. The research showed that the companies divide the costs spent on occupational safety within the company, the Industry 4.0 seems safe for them in most cases, however, it is important to make preparations (precautions) for these factors during the planning and implementing of the 4.0 concept, which is not a legal obligation in certain categories.

3.2. System Dynamics

The method of system dynamics is suitable for modelling, simulation, analysis, and the suggestion of dynamic complexity. J.W. Forester developed this method for the application of trade problems in the 1950s [9]. The aim of this method is to explain the behaviour of a system. It concerns the modelling of appropriate systemic structure. It is based on five fundamental elements, such as the causal relations of feedback, delay, non-linearity, and inventory. It is applicable to quantitative and qualitative modelling as well [6].

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The development of the model is divided into 4 steps [23]:
- characteristics of the problem,
- setting up a dynamic hypothesis,
- setting up a simulation model,
- testing and evaluation.

A complex of inter-acting elements is obtained during the setting when the purpose of the system needs to be emphasized. We view individual interactions as links and traditionally call them linkages. The complex systems are open, or closed, soft, or hard. The diagrams of states and flows are a fundament of the model. The flow changes the surface in time. It is a process that fills up or drains the level. Whereas the level has a memory, the flow is unstable. The flows in the model present the transfer of quantity to and from the levels or between them [7].

4. Results and Discussion – The Proposal of Risk Assessment Model Regarding Vehicle Construction Systems' Safety

Industry 4.0 brings about automation, robotization, artificial intelligence, machine learning, advanced communication methods, big data, and so forth, and the ways enterprises operate have been changing for decades. The transition to this concept brings about new risks when workers must cooperate with collaborative robots, and autonomous systems, and learn new things different from the previous systems. They are increasingly confronted with the technological environment. The standards and regulations to detect risks and secure workers' health have been already implemented in relation to the previous systems. The onset of the Industry 4.0 presumes a new framework for risk assessment and a new perspective on the development of health and safety in the automotive sector. The implementation of Industry 4.0 is not crucial in terms of its realization, but enterprises ought to ask several fundamental questions before putting it into operation [8]:
- How will the Industry 4.0 concept (project) change the automotive sector workplace?
- How will the Industry 4.0 concept (project) change the workload or work intensity?
- What is the aim of implementing the Industry 4.0 concept in automotive?
- What will be the benefits of this project (concept)?
- Are only managers participating in the change or is the process of change also being transferred to workers?
- How are the risks changing after introducing the Industry 4.0 concept?
- Is it economically beneficial to implement the Industry 4.0 concept in the vehicle manufacturing company?

If we render the implementation of the concept as a project, it can be based on the fundamental idea of risk assessment. Every project brings about individual risks. There is a contextual risk, which ought to be at no more than 20%, and known risks, which are the same in most

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cases as in the previous projects. Figure 1 shows the basic idea of risk assessment, which is applicable to the individual parts of every project.

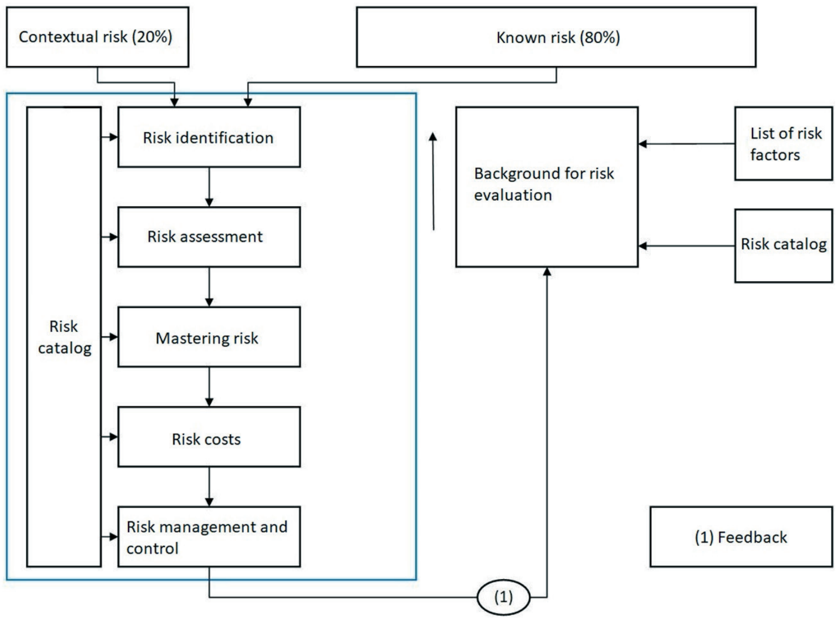

Fig. 1. The process of risk management regarding the automotive sector. Source: authors

4.1. Risk Identification

The process of risk management for the Industry 4.0 project is based on risk identification, which is a fundamental step and can influence the whole project. It is necessary to ask several fundamental questions during the determination of risks:

- What is the probability that the specific risk happens?
- If the selected risk takes place, what will be its effect and consequence?
- Has a plan to master the risks been defined?
- Concerning the probability of risk and its potential impact, what will be the priority in risk management?
- Who will be responsible for what risk?

The process of risk identification can be commenced when the fundamental answers have been defined.

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4.2. Risk Assessment

It is possible to determine probability and effects by taking the following step to identify the risk. In case the list of potential risks that could influence the whole project has been made, it is necessary to quantify the probability of the incidence of each risk and its impact. The estimation of risk is a process immediately following the identification of danger. The idea of the degree, i.e. the severity, of risk is formed on the base of the estimation of risk.

The risk mitigation coefficient (Rre) is implemented during risk evaluation. Rre is implemented because evaluators tend to "underestimate" risks either consciously or unconsciously at the expense of safety. The values of P and C are multiplied by the Rre coefficient. The whole process of risk assessment is the meaning of implementing the coefficient. The size of the coefficient is determined by the specific riskiness, and personalities of evaluators, and it can change in time.

4.3. Mastering Risk

At the moment of determining the list of risks and the quantification of risks, it is necessary to create a strategy for each risk. It is the determination of a solution in case of risk occurrence. All the parties involved select a priority risk from the list after the risk has been identified. It is possible to consult previous projects, experience, or an external expert in selecting and assessing risks. When the process of risk assessment has been completed, the register of risks or the plan of risks is created for the project.

The register of risks is regarded as an ideal instrument for managing and mastering risks and it is their synthesis. The risk register ought to contain the individual types of risks of the project lifespan, the determination of impact probability on the whole project, the person responsible for the individual types of risks, and the measures for mastering risk. The register of risks must be regularly monitored and updated in the course of the whole process.

It has been stated in Figure 1, where contextual risks account for 20% of every project, and the participants have not had to deal with them so far. The instruments for risk management are methods that can be applied to individual risks or to the whole project.

4.4. Creating the Template of the Risk Matrix

It is necessary to define a severity scale first during the creation of a risk matrix. It will correspond to the columns of the matrix and measure the severity of the effects of every risk. There are five levels in the 5 x 5 matrix:

- Insignificant (1): the consequence of the risk will be small if it happens.

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- Minor (2): the consequences of the risk will be easily manageable.
- Significant (3): it will take a certain time to mitigate the consequences of the risk.
- Major (4): the consequences of the risk will be significant and can cause long-term damage.
- Severe (5): the consequences of the risk will be really detrimental and it will be probably difficult to recover.

Then you will have to define the scale of probability that will correspond to the lines in the risk matrix. This scale estimates the probability that every risk will really take place.

- Almost certain (5): this risk will surely appear at a certain moment during the project.
- Likely (4): there is a big chance that this risk will take place.
- Moderate (3): this risk can happen, but not necessarily. Good luck to you.
- Unlikely (2): this risk is improbable.
- Rare (1): there is a small chance that this risk will happen.

If you present a risk in the matrix based on its probability and severity, you can determine the degree of its impact. It is coded in colours from green to red, and it is assessed on a scale from 1 to 25.

- Low (1 to 6): these events are not likely to occur, but they would not have serious consequences for our project in the worst scenario. It does not need to be a priority in your project.
- Medium (7 to 12): detrimental, such events can slow down your project. At this moment it is necessary to adopt necessary measures during the project to prevent and mitigate their effects. If the risk receives assessment in this interval, it ought not to be underestimated.
- High (13 to 25): these risks can threaten your project unless you consider them in the course of planning. Concerning the fact that these risks with serious consequences are likely to take place, they ought to be a high priority during planning the project.

Table 1 shows the example of criteria for determining the risks of the project. Every project requires an individual approach to criteria setting.

Tab. 1. Criteria for determining risks

Probability	Effect	Impact
Almost certain	Insignificant	Low
Likely	Minor	Medium
Moderate	Significant	High
Unlikely	Major	
Rare	Severe	

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The following Table 2 shows the possibility of creating a risk matrix based on criteria. It is a point determination of every risk. If the values get into the red area, they are the risks with a high-risk impact and must obtain a priority solution.

Tab. 2. The example of the risk matrix

	Insignificant (1)	Minor (2)	Significant (3)	Major (4)	Severe (5)
Almost certain (5)	5	10	15	20	25
Likely (4)	4	8	12	16	20
Moderate (3)	3	6	9	12	15
Unlikely (2)	2	4	6	8	10
Rare (1)	1	2	3	4	5

It is important to determine the risks and provide the safety of the whole vehicle construction process within the concept of Industry 4.0. One of the ways to ensure the safety and reliability of the whole system is to suggest the process of assessing the safety of vehicle construction systems in the conditions of Industry 4.0. The whole process can be divided into main and supportive processes. It is necessary to determine the principle of homogeneity and relevance within the proposal of assessing the safety of vehicle construction systems in Industry 4.0. Safety is assessed by the similarity of danger or activity based on homogeneity. Relevance shows the feasibility of risk analysis, i.e. to determine whether the size of the process is so enormous and if it is necessary to divide it into individual units or to assess it as a whole. Dynamic risk assessment is based on systemic risk analysis and dealing with risks. The process approach begins with creating a general model for risk assessment that will provide the complex safety of the process.

Figure 2 shows the fundamental risk model for creating a methodology for the safety assessment of vehicle construction systems in the conditions of Industry 4.0. The risks can be divided into four fundamental groups in all parts of the project. It is possible to define inter-links between individual risk groups with the help of system dynamics (as notable in Figure 2).

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Fig. 2. The model of system dynamics for risk assessment in the automotive sector. Source: authors

Financial risks – they concern various areas based on the paper where they are being analysed within the review process. The model of system dynamics shows that financial risk influences other risks that can appear in the project. They can be linked to capital investments in the new concept by using credit, subsidies, own income, inflation, and the development of currency exchange rates. It can also include the costs of the operation of the project from its approval to the operational period of the whole process; determining the benefits and financial influence of the concept on its whole life cycle, and even also Life Cycle Cost (LCC).

Service risks – service risks influence financial risks and vice versa. In case service is not provided throughout the whole lifespan of the facility, it will be a burden for the enterprise from a financial perspective. Service risks are linked to the provision of a guarantee for the whole concept, providing spare parts for the whole period of the facility's lifespan, and providing reviews of spare parts availability. This risk area ought to include vehicle construction system maintenance and its related risks as well. Service risks are closely connected to technological risks.

Technological risks – there is a connection between technological risks and legislation as the increased demands for technological progress increase the risks in legislation. The other influencing area is the risks of human agents as higher technologies create greater demand

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on the human factor and new risks are emerging. This category covers the whole technological support related to operation, development, and maintenance. This category reflects technological–operational parameters, supplying parameters, permits to operate, and revisions.

Legislative risks – the increase of legislative risks increases financial risks. Legislative risks are linked to fundamental legislation on the given issue, legal regulations, rules, industrial law and their implementation into practice, and supervision.

Managerial risks – managerial risks influence all risks entering the project, especially in its first part, under the causal loops of system dynamics. These risks are linked to the management of the whole project and its function from the beginning to bringing it into operation and during the operation.

Commercial risks – commercial risks influence managerial risks and decisions on the focus of project and market strategies. They concentrate on production or services under the demand of customers and commercial terms.

Human agent's risks – human agent's risks influence mainly technological, financial, and service risks, but they also enter other categories as well. They are linked to providing human resources that are needed to carry out all the activities during the whole project, but also during the operation of the facility. They include robots, vehicle manufacturing lines, computers, supervisors, administrative activities and so on.

Supply risks – supply risks influence, above all, commercial and managerial risks. This category includes providing supply terms, the level of provided services, the prices of individual supply products, etc.

The model of system dynamics with the help of causal loops has proved that the individual risk categories are usually projected into other areas, as they are closely interlinked.

The proposal of the process assessing the safety of vehicle construction systems in Industry 4.0. is based on Figure 3. The first model is the aim of the project itself. The intention of the project comes from the idea of implementing the concept of Industry 4.0. into an enterprise. It is the first and fundamental part of realizing the implementation of Industry 4.0. The enterprise ought to become aware of the need and the prioritization of the project and the associated risks.

Figure 3 shows a complex model of assessing the safety of vehicle construction systems in automotive under the Industry 4.0 conditions divided into three fundamental parts. The individual parts are further divided into partial units as it is necessary to assess the whole process in a complex way. In principle, the fundamental list of activities is to be made and potential risks influencing general safety are to be determined.

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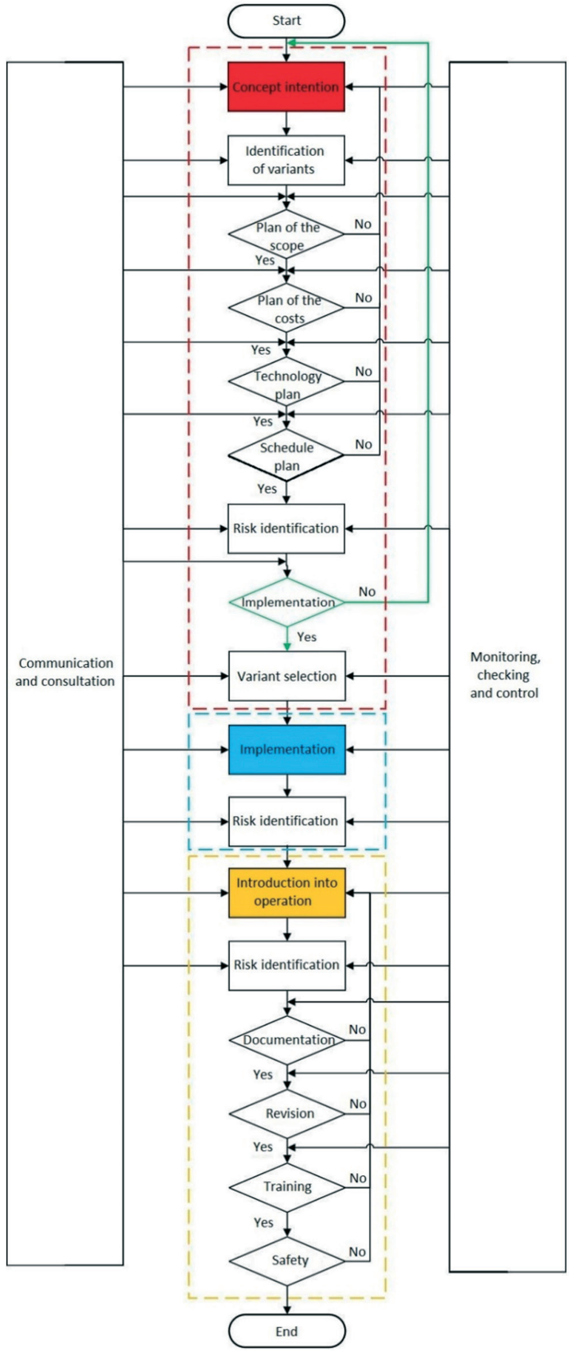

Fig. 3. The model of assessing the safety of vehicle construction systems in the conditions of Industry 4.0. Source: authors

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5. Conclusion

The aim of the paper was to design a model assessing the safety of vehicle construction systems in the conditions of Industry 4.0. The proposal was processed with regard to the paradigm of Industry 4.0. The integration of digital technologies and new production technologies offers automotive (i.e., vehicle manufacturing) companies to increase their productivity and, consequently, competitiveness. On the other hand, it is necessary to note that Industry 4.0. modifies the organization of work, and the related work risks. Risk assessment was necessary in the case of earlier facilities as much as it is necessary to assess the risks of the whole new technology when it is used now. The paper deals with risks that have existed since introducing the concept of Industry 4.0. The new model of risk assessment of vehicle construction systems in the Industry 4.0. was suggested on the basis of general procedure.

The newly proposed model was divided into three segments, where the risks must be categorized. The first part dealt with the concept of the project for the Industry 4.0. when the idea of the project focused on the Industry 4.0. was being formed. The second part was the implementation of the project selected variants. The last part of the process of assessing the safety of vehicle construction systems in the conditions of Industry 4.0. was bringing it into operation and the operation itself.

The most important process in the whole proposal of assessing the safety of vehicle construction systems in Industry 4.0. is the last process of bringing into operation. It is necessary to have properly processed directed documentation, secured entry revisions, revision plan, training of operational staff, and safety to bring it into operation and to operate. It is possible to include training, revisions, and safety to provide these parts of bringing it into operation and to operate more easily.

Safety can be divided into two parts, i.e., general safety and cyber safety, in the model. Cyber safety is obligatory in the current legislation in the Czech Republic only for the subjects of critical infrastructure. On this basis, cyber safety can be divided into the operator of basic service, manager of information system, and operator of information system of basic service. Enterprises that are not subject to legally obliged cyber safety provide it on a voluntary basis. The newly created model points to the necessity to provide cyber safety for any project focused on Industry 4.0.

The paper's contributions to the scientific field are especially as follows:
- The draft model for general assessing the safety in the Industry 4.0.
- The use of system dynamics approaches for risk assessment and searching for inter-links.
- The draft proposal of risk management in the process of vehicle construction systems' safety.

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The paper's contributions to pedagogy are as follows:

- Elaborating a case study that can be used in the pedagogical process.
- Elaborating a knowledge basis used for teaching the course of Process safety and reliability, and informatics in the area of cyber safety and related topics.
- Studying and processing the pertinent materials in the area of risk identification.

The paper's results represent a contribution to practice in the following fields:

- The possibility to set up processes and coordinate the whole project concerning automotive.
- The proposal for fundamental risks in the automotive sector during the project focused on Industry 4.0.
- Using the created catalogue of risks for the whole project.
- Using the model for searching risks in Industry 4.0.

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