SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2021
ORGANIZATION AND MANAGEMENT SERIES NO. 151

RISK MANAGEMENT ELEMENTS IN THE PRODUCTION OF A SELECTED AUTOMOTIVE PRODUCT

Andrzej PACANA[1*], Karolina CZERWIŃSKA[2], Paulina ZWOLENIK[3]

[1] Rzeszow University of Technology; Faculty of Mechanical Engineering and Aeronautics, Rzeszow, Poland; app@prz.edu.pl, ORCID: 0000-0003-1121-6352
[2] Rzeszow University of Technology; Faculty of Mechanical Engineering and Aeronautics, Rzeszow, Poland; k.czerwinska@prz.edu.pl, ORCID: 000-0003-2150-0963
[3] Ignacy Lukasiewicz Energy Policy Institute, Jasionka, Poland; 153281@stud.prz.edu.pl, ORCID: 0000-0001-6154-2194
* Correspondence author

Purpose: The study aimed to locate and identify weak areas in the technological process of the aluminium piston, where the occurrence of events with significant risk could interfere with its proper course and meet the customer's requirements.
Design/methodology/approach: One of the production lines on which the aluminium pistons are produced was chosen for the test. Risk identification within the process was carried out through the implementation of a simplified SWOT analysis, development of the process risk structure taking into account the identified opportunities and threats and development of a matrix for responding to key risks identified in the risk structure.
Findings: The three most significant risks were identified: failure to meet customer requirements, delays in delivery of castings, forgings, components and errors in monthly production plans, as well as increased process costs. The most effective actions concerning the risks under consideration turned out to be: drawing up detailed records in the description of the subject of the contract, as well as additional supervision and inter-operational controls and performing detailed analysis of the documentation before the beginning of the contract.
Research limitations/implications: In order to reduce the risks as part of the technological process, remedial actions and a response plan are proposed.
Practical implications: Future research will be carried out within the remaining technological processes within the company. The methodology presented should be applied to companies that are committed to responsible risk management.
Originality/value: The study is a useful material for manufacturing companies indicating a comprehensive methodology for identifying key risks within technological processes.

Keywords: SWOT analysis, response matrix, risk management, quality engineering, mechanical engineering.

Category of the paper: research paper and case study.

1. Introduction

The automotive industry is not officially classified according to PKD. Nevertheless, it is a separate branch, defined as a consequence of the automotive industry, considered to be as development. The automotive framework does not only include car manufacturing companies, but also organisations that create components for cars. According to the reports, this is an industry that is constantly developing and, like any other business, is subject to risks (Merkisz, 2009; Dąbrowski, Skrzypek, 2016; Wolniak, 2019; Sułkowski, Wolniak, 2013).

Despite its negative overtones, the word "risk" means a random event that can both weaken and strengthen the benefits of the process (Pacana, 2013; Czerwińska, Pacana, 2018). In the context of a manufacturing company it is referred to as a loss-making factor (Wolniak, 2015). Originally, risk studies were only aimed at determining the measure of uncertainty, together with an analysis of the probability of random events. Potential risks have been addressed through the use of redundancy, linked to increased costs. Examples of such a solution include increasing the dimensions of machine elements and engineering structures, increasing stockpiles or increasing the time reserve for task execution (Szomański, 2012; Serafin, 2013).

Risk management is treated in different ways. These include the division of duties and responsibilities of those involved in the production process, the establishment of rules for responding to adverse reactions and the definition of steps to eliminate or minimise the risk and consequently its effects. An extremely important aspect is to determine the probability of a risk occurring and its consequences through an analysis which includes a risk management matrix (Topczak, Patalas-Maliszewska, 2019).

The aim of the study was to locate and identify sensitive areas in the technological process of the aluminium piston, where the occurrence of events with significant risk could interfere with its proper course and meet the customer's requirements.

2. Risk management in the technological process

In the analysis of decision-making situations, taking into account the occurrence of risk, a result is obtained that is dependent on variables. The effect is not clear, but there is usually an indication of probable outcomes. From the point of view of the company and its activity, many risk categories can be distinguished (Wolniak, Skotnicka-Zasadzień, 2010). However, the most important ones concern financial, systemic and developmental areas of the organization. (Tarczyński, Mojsiewicz, 2001; Wolniak, 2011).

The current way of preventing and reducing the negative effects of risks is an activity that is called risk management. This solution reduces the possibility of adverse events by implementing preventive measures by prepares the necessary measures and establishes corrective methods to minimise the adverse effects of the peril. Risk management is one of the management techniques that rationalises decision making in case of uncertainty. This approach is considered to be the most effective – it minimises the economic expenditure of the company by reducing the probability of errors (Serafin, 2013; Pacana, 2018).

Risk management is a standardised technique, which is described in ISO 31000:2018. It refers to the organisation as a whole, but additionally discusses the processes implemented in it. The standard presents an iterative approach to risk management. The introduction of a process loop is aimed at an in-depth risk analysis which, through the skills and experience acquired, allows for revision of the process elements and controls at each stage. Repeated repetition of the technique allows to obtain the desired effect (Serafin, 2013; PN-ISO 31000:2018).

In standard 31000:2018, both the internal and external context of the organization are important, as well as the stakeholder who is equal to the participants in the organization. The parties include companies and individuals who work with the company and who are key to risk management by providing information, views or consultations. Communication at this level allows for the acquisition of the relevant information needed to make decisions (PN-ISO 31000:2018; Topczak, Patalas-Maliszewska, 2019).

Standardised risk management is based on three spaces. The first area concerns principles that include integration, structuring and comprehensiveness, customization, inclusion, dynamism, having the best information, paying attention to the human and cultural factor, also continuous improvement, through iteration. These provisions are intended to reflect the rationale behind risk management in an organisation. Another area for developing an informed understanding of danger is the risk management framework. These include a cycle that starts with risk surveillance and then goes on to design solutions, implement, evaluate and improve actions. The final space refers to the identification of the different stages of risk management (PN-ISO 31000:2018; Ząbek, 2019):

- establishing the context and extent of risks,
- risk identification,
- risk analysis,
- risk assessment,
- risk elimination,
- registration and reporting,
- communication and consultation,
- monitoring and review.

The risk management steps should be carried out systematically and iteratively, using stakeholder knowledge resources. It should contain information, supplemented by additional inquiries. The main purpose of identifying risks that may result in an organisation's inability to achieve its objectives is to find, identify and describe them (Kokot-Stępień, 2015; Topczak, Patalas-Maliszewska, 2019).

The main objective of risk assessment is to support the decision-making process by comparing the results of the analysis with established criteria in order to obtain areas for action. The occurrence of risk sometimes needs to be remedied, which is the process of dealing with peril. This process includes iterative formulation and selection of risk corrections, as well as planning and implementation of corrective actions, with appropriate assessment and decision making on the next steps. Important aspects that should be taken into account when undertaking risk repair are costs, inputs and potential dangers, which include eliminating the current danger in favour of a new irregularity. The following ways of correction can be distinguished (Majewska, 2011; Topczak, Patalas-Maliszewska, 2019):

- minimise risk-causing activities – avoid the risk,
- take or increase the risk,
- eliminate the source of the risk,
- update the probability and/or consequences,
- share the risk,
- decide to leave the risk.

An important element of risk management is monitoring and reviewing activities. Their purpose is to strive for process excellence, through supervision, reporting and communication with stakeholders. The information obtained allows for effective decision making, as well as control of actions, together with monitoring of management progress (Małyszek, 2015; Topczak, Patalas-Maliszewska, 2019).

The use of risk management models and techniques in firms must comply with the normative acts. The methods used in this solution are divided into quantitative (e.g. SWOT analysis) and qualitative (cataloguing risk factors) (Górski, Skorupka, 2011; Topczak, Patalas-Maliszewska, 2019).

3. Description of the analyzed technological process

The technological process is an essential part of the production process, which is directly related to changing the dimensions, shape, surface quality and physico-chemical properties of the processed product or determining the mutual position of units or parts in the product (Wodecki, 2011; Feld, 2009; Muhlemann et al., 2005). From this definition results the function of the technological process, which is to change the condition of the workpiece from the initial state (semi-finished product or input material) to the final state – finished product (Szatkowski, 2008).

The technological process analysed refers to the technical operations necessary to produce an aluminium piston intended for light diesel vehicles. The input material of the technological process is aluminium alloy together with various alloying additions. The acceptance operation, i.e. inspection, is the basis for verifying the piston in terms of quality. The material structure, the appropriate properties and the shape of the workmanship or the dimensional accuracy of the product's surface are a prerequisite for its reception and correct installation in the engine crank system. Table 1 shows a shortened technological process, i. e. technological operations in which there is a change of physicochemical properties, shapes, the external appearance of the processed material to produce a diesel engine piston.

Table 1.
Shortened technological process of the piston in question

Operation number	Name operation	Device characteristics/station	Treatments
10	Casting	Semi-automatic position	- melting and finishing of the alloy - casting liquid alloy
20	Cleaning castings	Manual position	- removal of the gating system - rough cleaning - thorough cleaning
30	Heat treatment	Furnace	- heat treatment of castings
40	Turning	Okuma Lu15	- stamp the pistons coat and bottom
50	Extrusion	Varmo Clement	- coarse extrusion of the pin hole
60	Turning	Okuma Lcc15-2s	- turning the combustion chamber
70	Milling	Ernault ID2000	- valve milling
80	Turning	Cost	- turning of sealing channels - base turning
90	Extrusion	Frontor C1 FB	- extrusion of the pin hole on the finished
100	Chemical treatment	Tubalex i Dubuit	- phosphating process - graphitization process
110	Control	Checkpoint	- interoperable control - receiving control - final control
120	Installation	Mounting station	- seger and pin assembly - installation of sealing rings

Source: documents provided by the Federal Mogul Gorzyce. Unpublished materials, Gorzyce, 2014.

From the information contained in Table 1 concerning the course of the technological process, it results that the process of manufacturing the aluminium piston consists of 12 main technological operations under which appropriate technological operations are carried out. The illustrative presentation of the manufacturing process does not include inter-operational transport, quality control and storage.

4. Research methodology

Risk management provides an opportunity to assess the risk of production processes by identifying and categorising risk factors. The risk assessment of risk factors in the methodology was carried out according to the following steps:

Stage 1: development of a simplified SWOT analysis for the implementation of the technological process in the context of achieving a specific objective.

Stage 2: identification of opportunities and threats occurring within the implementation of the production process.

Stage 3: development of the process risk structure taking into account the identified opportunities and threats.

Stage 4: development of a response matrix to key risks identified in the risk structure.

Stage 5: development of a response plan.

Stage 6: monitoring of the process.

Stage 7: launch of a response plan.

Stage 8: assessment of risk management.

The presented next steps of the undertaken methodology will allow to improve the production process of aluminium pistons.

The survey was carried out in the fourth quarter of 2019 in one of the automotive companies based in the south-eastern part of Poland. One of the production lines on which the aluminium pistons intended for dogs' cars are produced was selected for the test. The tested production line operates in a 3-shift system.

5. Strategic process analysis of aluminium pistons

The risk management study was used to identify critical events with significant risk, which may disrupt the achievement of the main objective, which is to produce the pistons compliant with the client's requirements in the planned quantity on time.

In order to identify risk factors, a team of experts (composed of a production manager, a quality manager, a quality controller and a technologist) developed a simplified SWOT analysis for the implementation of the technological process in terms of achieving a specific objective – timely production of pistons, in the planned quantity and accordance with customer requirements (Table 2). The analysis made it possible to highlight the main internal strengths and weaknesses of the process, as well as its external sphere in the form of opportunities and threats. Based on the analysis, it was possible to identify internal opportunities and threats to the process implementation.

Table 2.
Simplified SWOT analysis

Strengths	**Weaknesses**
Knowledge of production processes	Large production area
Experienced staff	Underutilisation of production capacity
Versatility of employees	Large number of machine retooling within the process
Several decades of experience in piston production (Know How)	Poor communication between support departments
Involvement of employees (Kaizen)	Sudden increase in production plan
Standardisation of production (5S)	
Quality stability	
Continuous improvement (SPC, Kaizen, 5S)	
Opportunities	**Threats**
Reducing deficiency levels	High turnover of employees
Reduced cycle times	Delays in the production plan
Reduction of changeover times (SMED)	
Improving productivity through automation	Increased deficiency levels
Flexibility of production	Breakdowns
Improving employee awareness through internal and external training	Possible lack of crew
	Random events
Opportunities to launch new projects	Delays in the delivery of inputs
Increase in OEE	Disappearance/lack of media

Analysing the results of a simplified SWOT analysis, one can notice that the production process has more strengths than weaknesses, and there are more opportunities than threats in its environment. In this situation, process managers should build on their strengths to maximise the externalities of the process environment and make efforts to reduce or eliminate weaknesses in the process and prevent risks. Based on simplified SWOT analysis, a risk structure for the process was developed (Figure 1). This includes an element such as material resources/equipment, human resources/knowledge/training/skills, process input and output element and process indicators against which potential risks have been identified. The risk structure of the technological process also includes documents regulating its implementation.

In the risk structure, several risks were identified about the separate planes in the analysis, as well as the three most serious risks, which were: failure to meet customer requirements, delays in the delivery of castings, forgings, components and errors in monthly production plans, as well as an increase in process costs. The common feature of the presented threats is their high probability. This means that the specified qualitative, timing and cost risks also generate a high level of risk.

It is impossible and inefficient to include all identified activities in a risk management plan at the same time - mainly for time and financial reasons. Appropriate measures should therefore be taken which are most effective under the circumstances. To this end, risk response matrices should be used (Pritchard 2002).

	Risk		
Material resources/devices			**Human resources/ knowledge/training/skills**
- Machinery - Measuring and control equipment - Castings, forgings, components - Auxiliary materials - Processing equipment - Tools - Media	- Machine and equipment failures - Inappropriate tooling - Quality/ quantity of castings/components - Quality capacity of machines	- Staff qualifications - Absence of employees - Staff turnover	- Staffing according to the skills matrix - Staff experience and knowledge - Training plan
Entrances			**Outputs**
- Production plan - SAP - Replacement orders - Production orders - Control plan - Customer requirements - Castings, components - Legal requirements - Continuous improvement - Shipping plans	- Failure to meet customer requirements - Delays in the delivery of castings, forgings, components - Errors in monthly production plans - Increase in process costs		- Customer requirements - Continuous improvement - Compatible pistons - Customer satisfaction
Process indicators			**Documents/procedures/ instructions**
- Timely implementation of the monthly plan - Lack of working capacity indicator - Number of pistons advertised (ppm) - OEE	- Exceeded execution and delivery deadlines - Exceeded ratio of non-compliant products - Customer complaint - OEE ratio below target	- Outdated inspection plans/instructions - Availability of CSR - Availability of inspection plans, instructions, technical documentation	- Inspection plan - Work instructions - System procedures - Visualisations - Customer requirements - Technical documentation - Guides

Figure 1. The structure of the risks in relation to the individual elements of the piston process.

Figures 2-4 present matrices prepared based on the above analyses of threats to the implementation of the technological process of the aluminium piston and possibilities of counteracting them. The matrix in Figure 2 refers to threats that result in a qualitative risk, the matrix in Figure 3 to those that generate a scheduled risk, while the matrix in Figure 4 refers to those that generate a cost risk. In the columns of the matrix, there are presented actions allowing to limit the frequency of events generating the most significant risks – rows of the matrix. The plus (+) or minus (-) marking occurs at the intersection of columns and rows depending on whether the measure under consideration has a positive or negative effect on the risk factor under consideration.

Threat \ Responsiveness	Additional supervision and inter-operational checks	Detailed provisions in the description of the subject of the contract	Detailed analysis of the documentation before starting the works	Frequent maintenance of machines and equipment	Repairs, maintenance	Course trening
Errors in technological documentation	+	+	+			+
Quality of castings and components	+	+	+	+	+	+
Number of castings and components	-	-	-	-	-	
Incompatible materials and component damage	+	+	+			
Incorrect machine tooling	+	+	+			+
Extension of the time for the execution of post-secondary technological operations	+	+	+	+	+	
Low level of reproducibility and repeatability of individual technological operations	-			-	-	-
The quality capacity of the machines				+	+	
Machine and equipment breakdowns				+	+	

Figure 2. Matrix for responding to quality risk in the piston process.

The presented analysis of the quality risk in the technological process indicates that the most effective measures to reduce this risk would be additional supervision and inter-operational controls, drawing up detailed records in the description of the subject of the contract and carrying out detailed analysis of the documentation before starting the contract.

Threat \ Responsiveness	Additional supervision and inter-operational checks	Detailed provisions in the description of the subject of the contract	Detailed analysis of the documentation before starting the works	Frequent maintenance of machines and equipment	Repairs, maintenance	Training courses	Bonuses, awards
Errors in technological documentation	+	+	+			+	
Number of castings and components	-	-	-	-	-		
Incompatible materials and component damage	+	+	+				
Incorrect machine tooling	+	+	+			+	
Extension of the time for the execution of post-secondary technological operations	+	+	+	+	+		
Delays in the supply of materials		+	+			+	
Machine and equipment breakdowns				+	+		
Machine collisions	+	+	+			+	
Absence of employees						-	-
Staff turnover						-	-

Figure 3. Timetable risk response matrix in the pigging process.

Concerning the scheduling risk (Figure 3), it has been noted that the most important contribution to preventing the risks is made by drawing up detailed records in the description of the subject of the contract and carrying out a detailed analysis of the documentation before starting the contract. On the other hand, the most effective way to reduce the cost risk in the technological process (Figure 4) was to draw up detailed records in the description of the subject of the contract, as well as additional supervision and inter-operational controls and detailed analysis of the documentation before starting the contract.

Responsiveness / **Threat**	**Additional supervision and inter-operational checks**	**Detailed provisions in the description of the subject of the contract**	**Detailed analysis of the documentation before starting the works**	**Frequent maintenance of machines and equipment**	**Repairs, maintenance**	**Training courses**
Errors in the technological documentation	+	+	+			+
Number of castings and components	-	-	-	-	-	
Incompatibility of materials and damage to components	+	+	+			
Incorrect equipment of machines	+	+	+			+
Extending the time of execution of individual technological operations	+	+	+	+	+	
Failure of machines and equipment				+	+	
Collisions of machines	+	+	+			+
Change in the scope of the customer's order		+				

Figure 4. Piston process cost risk response matrix.

The response plan relating to the riskiest events (quality risk event: failure to meet the customer's quality requirements, schedule risk: delays in the delivery of castings, forgings, components and errors in monthly production plans, cost risk: an increase in process costs) has carefully defined responsibilities and specific actions. The most effective actions concerning the risks under consideration turned out to be: drawing up detailed records in the description of the subject of the contract, as well as additional supervision and inter-operational controls and performing detailed analysis of the documentation before the beginning of the contract. In addition, the corrective action in the scope of failure to meet the quality requirements of the customer is to consider the complaint, compensation and delivery of quality compliant products. In the event of errors in monthly production plans, the production plan should be immediately corrected in terms of adequacy to the production situation and the delivery schedule and possibly corrected. In case of delays in the delivery of piston components, it is necessary to use the emergency stock of components and change the supplier.

As a precautionary measure against the most serious risks in the aluminium piston technological process, it was recommended to perform additional checks on the compliance of the variables taken into account with the actual state of affairs and their correctness. To ensure that the quality requirements of the customers are met, it is recommended to use job instructions and continuous monitoring of the process within the workstations and, in justified cases, to use quality management instruments following the procedures operating in the company. To prevent delays in the delivery of piston components, periodic supplier evaluations should be used.

6. Conclusion

The concept of risk within the implementation of technological processes is most often used in the aspect of risk management, which involves taking actions to reduce the probability of its occurrence, i. e. to protect against possible negative effects. The process risk analysis presented in the study makes it possible to identify, classify, measure and define methods of responding to situations with significant risk.

The study aimed to locate and identify weak areas in the technological process of the aluminium piston, where the occurrence of events with significant risk could interfere with its proper course and meet the customer's requirements. The analysis of the risk estimation made it easier to identify and at the same time to determine the size of losses in case of their occurrence. Reducing the risk associated with disruption of the process is possible thanks to effective risk management in the company, within the scope of which it is necessary to distinguish identification, planning, decision making and controlling the level of risk so that it is at an acceptable level. Therefore, the identification of actions to prevent the occurrence of the most serious risks can be considered the most important stage of risk reduction, which is made possible by the implementation and analysis of the response matrix. In the study, the most effective actions with regard to the risks under consideration turned out to be: drawing up detailed records in the description of the subject of the contract, as well as additional supervision and inter-operational controls and performing detailed analysis of the documentation before starting the contract.

The risk assessment should be carried out once or twice a year. This would allow for the identification of new forms of threats and the maintenance of an acceptable level of risk within individual processes carried out in the company.

References

1. Czerwińska, K., Pacana, A. (2018). Porównanie dokładności określania poziomu ryzyka zawodowego na stanowisku przemysłowym. *Zeszyty Naukowe. Quality. Production. Improvement, No. 1(8)*.
2. Dąbrowski, K., & Skrzypek, K. (2016). Wykorzystanie zintegrowanych systemów informatycznych w polskich przedsiębiorstwach produkcyjnych z branży metalowej i automotive. *Zarządzanie Przedsiębiorstwem, 19(4).*
3. Dokumenty udostępnione przez Federal Mogul Gorzyce (2014). Materiały niepublikowane. Gorzyce.
4. Feld, M. (2009). *Podstawy projektowania procesów technologicznych typowych części maszyn.* Warszawa: WNT.
5. Górski, M., & Skorupka, D. (2011). Wybrane metody identyfikacji czynników ryzyka na tle cyklu życia projektu i budowlanego procesu inwestycyjnego. *Zeszyty Naukowe*. Wyższa Szkoła Oficerska Wojsk Lądowych im. gen. T. Kościuszki.
6. Kokot-Stępień, P. (2015). Identyfikacja ryzyka jako kluczowy element zarządzania ryzykiem w przedsiębiorstwie. *Zeszyty Naukowe Uniwersytetu Szczecińskiego. Finanse, Rynki Finansowe, Ubezpieczenia (74, T. 1, Rynek kapitałowy, wycena przedsiębiorstw, inwestycje)*.
7. Majewska, J. (2011). Analiza wpływu obserwacji ekstremalnych na pomiar ryzyka. *Modelowanie Preferencji a Ryzyko, '11*.
8. Małyszek, E. (2015). Wybrane aspekty ryzyka w zarządzaniu łańcuchem dostaw. In: R. Knosala (ed.), *Innowacje w zarządzaniu i inżynierii produkcji*.
9. Merkisz, J. (2009). The automotive market in the time of global economic crisis. *Silniki Spalinowe, 48*.
10. Muhlemann, A.P., Oakland, J.S., Lockyer, K.G. (2005). *Zarządzanie. Produkcja i usługi.* Warszawa: PWN.
11. Pacana, A. (2013). *Wdrażanie, auditowanie i doskonalenie systemów zarządzania bezpieczeństwem i higieną pracy zgodnych z PN-N-18001.* Rzeszów: Oficyna Wydawnicza Politechniki Rzeszowskiej.
12. Pacana, A. (2018). Supervision of measuring equipment based on risk management and ISO 9001. *Production Engineering Archives, 21(21).*
13. Pałubicki, S., & Kukiełka, K. (2017). *Zarządzanie jakością w wybranym procesie produkcyjnym z zastosowaniem metody FMEA*. Autobusy: technika, eksploatacja, systemy transportowe.
14. PN-ISO 31000: 2018 – Zarządzanie ryzykiem – Zasady i wytyczne.
15. Pritchard, C.L. (2002). *Zarządzanie ryzykiem w projektach. Teoria i praktyka.* Warszawa: WIG-PRESS.

16. Serafin, R. (2013). Koncepcja systemu adaptacyjnego zarządzania ryzykiem dostaw w procesach produkcyjnych. *Zarządzanie przedsiębiorstwem, 16(3).*
17. Sienkiewicz, P. (2005). Analiza ryzyka w zarządzaniu projektami systemów. *Problemy techniki uzbrojenia, 34*.
18. Sułkowski, M., Wolniak, R. (2013). Przegląd stosowanych metod oceny skuteczności i efektywności organizacji zorientowanych na ciągłe doskonalenie. *Zeszyty Naukowe. Organizacja i Zarządzanie, z. 67*. Politechnika Śląska.
19. Szatkowski, K. (2008). *Przygotowanie produkcji*. Warszawa: PWN.
20. Szomański, B. (2012). *Znaczenie zarządzania ryzykiem.* Materiały III Ogólnopolskiej Konferencji pn. Dobre praktyki doskonalenia zarządzania – zarządzanie ryzykiem.
21. Tarczyński, W., & Mojsiewicz, M. (2001). *Zarządzanie ryzykiem: podstawowe zagadnienia*. PWE.
22. Topczak, M., & Patalas-Maliszewska, J. (2019). Model oceny poziomu ryzyka w przedsiębiorstwie produkcyjnym. *Zarządzanie Przedsiębiorstwem, 22(4).*
23. Wodecki, J. (2011). *Podstawy projektowania procesów technologicznych części maszyn.* Gliwice: Wydawnictwo Politechniki Śląskiej.
24. Wolniak, R. (2007). Unikanie niepewności a wdrażanie koncepcji zarządzania jakością. *Problemy Jakości, Nr 5*.
25. Wolniak, R. (2013). NW kierunku ISO 9001:2015. *Problemy Jakości, T. 45, Nr 02*.
26. Wolniak, R. (2019). Downtime in the automotive industry production process – cause analysis. *Quality, Innovation, Prosperity, 2*, pp. 101-118.
27. Wolniak, R., Skotnicka-Zasadzień, B. (2010). *Zarządzanie jakością dla inżynierów*. Gliwice: Wydawnictwo Politechniki Śląskiej.
28. Ząbek, J. (2019). The role of the organization's leadership in risk management according to norm ISO 31000: 2018. *Zeszyty Naukowe Małopolskiej Wyższej Szkoły Ekonomicznej w Tarnowie, 3(43)*.