Risk Analysis as a Way to Improve the Efficiency of Production Processes – Case Study

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Abstract. The importance of risk management in enterprises is constantly increasing, because it has influence on the company's leading positions, increasing its competitiveness in markets. It also helps to increase the efficiency of fundamental production processes by reduction of production losses. At present time, there is no unified assessment methodology of risk impact of the enterprise efficiency activity. Each enterprise uses independently developed methods for calculating the risk. The paper describes a methodology for analysing and assessing the risk in production system. The use of integrated methodology of risk assessment and analysis has been discussed based on case study from automotive company. The author describes the matter of performing identification of possible risks from 4M group (machine, material, method, man), their continuous analysis, assessment and mitigation method. This article features a case study by which production efficiency disturbing factors have been identified. Additionally, the risk levels have been assessed and process improving actions indicated.

Keywords: Risk · Risk assessment · Risk analysis · Risk management · Production process · Continuous improvement · 4M method

1 Introduction

The aim of contemporary enterprises is to constantly improve the areas of their activities. In order to do that, they use various methods and tools meant for identifying problems, weaknesses and the steps needed to be made to minimize or eliminate the possibility of their occurrence in the system [1, 2]. The issue of risk management tackles such actions. Proper, systematic and structured approach to risk management contributes to reduction of risks factors and, at the same time, it gives tangible benefits in the form of improving the effectiveness of all processes.

Managers seek to improve those areas of the production system where the strategic importance for the organization is essential and where the level of risk is the highest [3, 4]. In this dissertation, it has been assumed that the production losses are determinants of level of risk value because they reflect that the production processes in the system failed to accomplish assumed goals.

The areas of production systems that have been analyzed are in the first place related to the processes performed in the system. The input factors of those processes can be

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divided into four main categories: materials, machines, methods and men (4M) [5]. It is thought that the concept of 4M is the foundation of functioning of every company, hence it is impossible to optimize any kind of process without stabilizing the 4M area first. For this reason, this dissertation has taken the 4M area as the main factor of potential source of losses [6, 7].

Risk factors in these areas disrupt and obstruct the fulfillment of assumed goals in the system which impacts the effectiveness of production processes and reduces it. To reduce negative effect of risk factors in production systems, the company needs reliable and appropriate risk management and the introduction of an effective and comprehensive risk management methodology.

2 Literature Review

The methods used for analysis and risk assessment help enterprises to interpret the threats in the environment – risk factors resulting in failure to achieve goals and, furthermore, decrease in effectiveness of production systems. There are several dozens of methods of risk assessment and analysis used in theory and practice [8–12]. The most extensive classification of tools and methods for risk assessment and analysis is presented in EN 31010:2010 standard which specifies as much as thirty-one methods being used in economic practice [13].

In relation to their character, those methods can be divided into quantitative, qualitative and mixed. Although the aim is common - to minimize the risk - these methods present a broad spectrum of usage, ranging from expert reflection to methods based on creating schematics and logical event scenarios. Table 1 presents the list from EN 31010:2010 standard related to the possibility of applying chosen method in risk assessment and analysis.

Table 1. Selected methods of risk assessment and analysis.

Method	Risk identification	Risk analysis			Risk assessment
		Severity	Occurrence	Detection	
FMEA analysis	++	++	++	++	++
Tree decision model	–	++	++	+	+
Monte carlo	–	–	–	–	++
Cause/effect matrix	++	++	++	++	+
Check list	++	++	++	++	++
If-What analysis	++	++	++	++	++
HAZOP analysis	++	++	+	+	+
FTA	+	–	++	+	+
ETA	+	++	+	+	–
HRA	++	++	++	++	+
LOPA	+	++	+	+	–
Description: – not used + used ++ commonly used					

Comparing the collected data, it can be noticed that some methods have limitations in relation to their usage in contemporary production systems. Presented methods are not complex enough which means that they do not always contain identification of threats, their analysis or risk assessment.

With reference to the conducted overview [14, 15], similar conclusions can be made. The methods presented in literature focus on individual cases of managing given risk factor [16–19]. In order to assess the risk comprehensively, it is necessary to modify the method in order to enable its application. The analysis and value of risk level in each method should refer to the whole production system [20–22], rather than to individual issues, which would prove that the method is complex and universal. Also, the methods of analysis and risk assessment available in the market do not ensure the possibility of analysing risk factors in view of the sources of their occurrence. Moreover, these methods do not enable viewing those risk factors with reference to their categories and their value in each group.

3 Methodology of Risk Assessment

Risk management facilitates the risk assessment of the production process by recognition and then grouping the risk factors. The presented risk assessment methodology uses the fact of dividing risk factors into **4M categories (machine (1M), material (2M), method (3M), man (4M))** [23]. The 4M approach considers all the main sources of risk [24].

Mentioned risk factors have influences on planned realization of production plan, what is closely connected with processes effectiveness. The presented methodology refers to FMEA analysis - it allows to find problems in the organization and creates a space for improvement. The methodology divides the risk assessment related to the presence of risk factors into the following stages [25]:

STAGE 1: Identification of risk factors in the process by usage of standardized data collecting tools to find the risk.
STAGE 2: Categorization of risk factors - risk factors distribution into 4M categories. Each single case should be assigned to the appropriate category.
STAGE 3: Analysis of risk factors from each category including the frequency of **occurrence (O), severity** of their impact **(S)** and probability of their **detection (D)** – based on proposed evaluation criteria.
STAGE 4: Assessment of risk level:

- **Single Risk Indicator** (**SRI**) regarding 4M categories - (SRI1M, SRI2M, SRI3M, SRI4M),
- **Risk Level Indicator** (**RLI**) regarding 4M categories - (RLI1M, RLI2M, RLI3M, RLI4M),
- **Total Risk Indicator** in production systems (**TRI**).

STAGE 5: Implementation of improvement actions to remove or minimize risk occurrence. Based on Pareto principle – 80% of consequences come from 20% of the causes. Therefore, the implementation of appropriate improvement actions for the upper 20% of risk level indicators should minimize the risk of system disruptions.

4 Risk Assessment for Production Processes – Case Study from Automotive Sector

The case study was conducted in the second half of 2017 in an automotive industry business. It focused on risk management to guarantee the efficiency of production process by losses reduction. The study consists of three months of analysis (June, October, November), when production losses were dominant – Table 2. The assembly line – A1 chosen for the study produces safety valves for truck semi-trailers.

Table 2. Period of production losses's analysis.

Production line A1	6/2017	7/2017	8/2017	9/2017	10/2017	11/2017	12/2017	Sum
Production goal [pcs]	5421	4494	3447	5563	4497	4970	3527	31919
Production output [pcs]	4066	4676	4082	5237	2719	3645	3363	27788
Difference [pcs]	1355	−182	−635	326	1778	1325	164	4131

The goals of the presented analysis were to assess process risks by identifying and categorizing risk factors occurring during production process and to establish corrective activities to improve process efficiency.

In order to specify the reasons of loss in efficiency, hence identification of risk factors on analysed assembly line, the data from hourly control cards were tracked. Production line workers recorded the number of units produced at each working hour. They then compared the result with the target hourly output. If the goal was not achieved, it was necessary to explain the reason and determine the duration of the production line downtime. Following data allowed to determine the cause of the failure in achieving the target production efficiency Based on this simple tool, risk factors have been established along with their frequency of occurrence and duration. The results of analysis of hourly control cards are shown in Fig. 1.

The presented graph shows that the main risk factors are closely connected with each other. The tester's and tool equipment's breakdowns (every month, the breakdown of screwdriver, table's sensor or lubricator has occurred several times) resulted in production of faulty items and consecutive error analysis, as well as in set up of assembly line. During three analysed months, the noted production losses summed up to 157 h. Additionally, the amount of losses has been supplemented with the production leader's data regarding employee's absence. In such cases, assembly line has not been started and hourly control cards have not been filled. The stoppage of line during the analyzed period summed up to almost 404 h.

In the next step of analysis, the identified risk factors have been divided into 4M categories. In the case of line A1, this categorization looked as follows:

- Machine (1M) – 9% (equipment breakdown, tester breakdown, settings/adjustment of the tester after changeover),

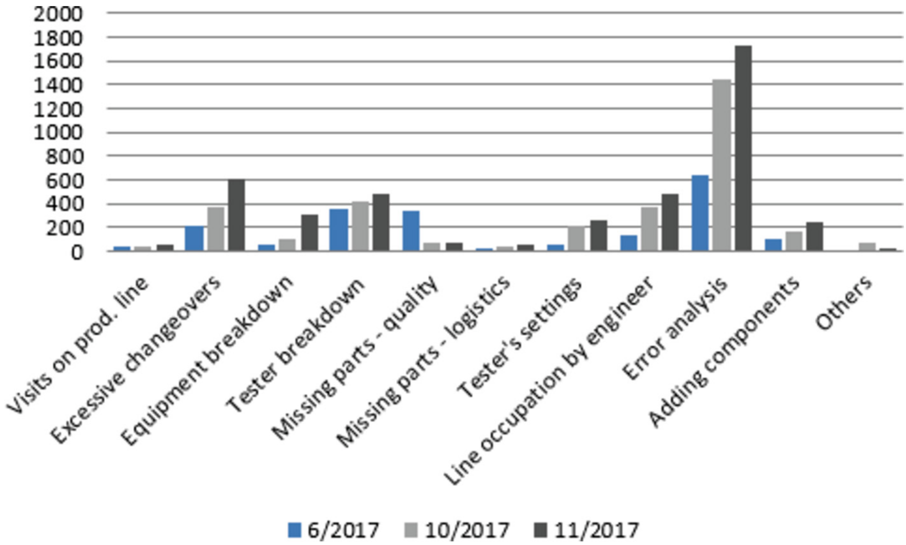

Fig. 1. Production losses of A1 line.

- Material (2M) – 34% (missing components due to logistics or quality issues),
- Method (3M) – 27% (excessive changeovers, production line occupied by engineer, error analysis by assembly operator, adding components, training of employees, visits on production line,)
- Man (4M) – 30% (absence).

Subsequently, the identified risk factors were analyzed according to the frequency of their occurrence, severity of the impact and probability of their detection. The analysis was conducted in accordance with the suggested assessment criteria and its results are presented in Table 3.

Table 3. Analysis of risk factors.

Cat.	No.	Risk factor	Frequency of occurrence		Severity of the effect		Probability of detection	
1M				O1M		S1M		D1M
	$1M_1$	Equipment breakdown - screwdriver	3x6/2017 3x10/2017 3x11/2017	5	Total stoppage: 395 min	4	High probability of risk's factor detection and its reason	3

(*continued*)

Table 3. (*continued*)

Cat.	No.	Risk factor	Frequency of occurrence		Severity of the effect		Probability of detection	
		Equipment breakdown - sensor	1x6/2017 2x10/2017	4	Total break: 50 min	3	Middle high probability of risk's factor detection and its reason	4
		Equipment breakdown - lubricator	1x11/2017	3	23 min	3	Ongoing controls will certainly detect the risk's factor as well as its cause	1
	$1M_2$	Tester breakdown	2x6/2017 1x10/2017 2x11/2017	5	Assembly stoppage for 1258 min in total	6	Medium probability of risk's factor detection and its reason	5
	$1M_3$	Settings of tester after changeover	6x6/2017 16x10/2017 16x11/2017	8	Total stoppage: 517 min	4	Ongoing controls will certainly detect the risk's factor as well as its cause	1
2M				O2M		S2M		D2M
	$2M_1$	Missing parts due to logistic issues	1x6/2017 3x10/2017 3x11/2017	3	Stoppage of 115 min in total	3	Risk factor will certainly be detected	2
	$2M_2$	Missing parts due to quality issues	17x6/2017 4x10/2017 3x11/2017	4	Break of 464 min	4	Risk factor will certainly be detected	2

(*continued*)

Table 3. (*continued*)

Cat.	No.	Risk factor	Frequency of occurrence		Severity of the effect		Probability of detection	
	$2M_3$	Missing parts from suppliers	3x6/2017 1x11/2017	4	Total stoppage 17 shifts	10	V. high probability of detection	1
3M				O3M		S3M		D3M
	$3M_1$	Excessive changeovers	23x6/2017 25x10/2017 33x11/2017	7	In total 1176 min of offline	4	Ongoing controls will certainly detect the risk's factor as well as its cause	1
	$3M_2$	Assembly line occupation by engineer	7x6/2017 13x10/2017 7x11/2017	6	In total 973 min of line stoppage	4	Medium probability of detection via current controls. The detection of the cause of risk is likely	5
	$3M_3$	Error analysis by assembly operator	23x6/2017 25x10/2017 33x11/2017	7	Total stoppage 2507 min	5	Medium probability of detection via ongoing controls. The detection of the cause of risk is likely	5
	$3M_4$	Adding components	8x6/2017 7x10/2017 7x11/2017	6	Total line stoppage 491 min	4	V. high probability of detection	2

(*continued*)

Table 3. (*continued*)

Cat.	No.	Risk factor	Frequency of occurrence		Severity of the effect		Probability of detection	
	$3M_5$	Visits on assembly line	3x6/2017 3x10/2017 4x11/2017	4	Assembly offline 120 min in total	3	Probability of risk factor detection and its cause is v high	2
4M				O4M		S4M		D4M
	$4M_1$	Absence of employees	3x6/2017 1x10/2017 13x11/2017	8	Lack of staff for 16 shifts	10	Probability detection is v low. Minimal supervision of HR	7

The next step was to assess the risk of the analyzed process based on the established formulas [14]. Firstly, value of Single Risk Indicators (SRI) for each category were calculated. Value of SRI for first factor in the Machine category ($1M_1$) - that is equipment breakdown – equals:

$$SRI1M_1 = \sum_{i=1}^{n} (O1M_1 \cdot S1M_1 \cdot D1M_1) \tag{1}$$

hence

$$SRI1M_1 = (5 \cdot 4 \cdot 3) + (4 \cdot 3 \cdot 4) + (3 \cdot 3 \cdot 1) = 117 \tag{2}$$

Value of $SRI1M_1$ for equipment breakdown equals 117 units. Values of SRI for factors second and third correspondingly equal:

$$SRI1M_2 = 5 \cdot 6 \cdot 5 = 150 \tag{3}$$

$$SRI1M_3 = 8 \cdot 4 \cdot 1 = 32 \tag{4}$$

Then, having the values of all risk factors from each category, value of Risk Level Indicator (RLI) for the machine category RLI1M could be calculated:

$$RLI1M = \sum_{i=1}^{n} RLI1M_i \tag{5}$$

hence

$$RLI1M = 117 + 150 + 32 = 299 \tag{6}$$

According to the established formula, value of Risk Level Indicator for the machine category RLI1M is 299 units.

The calculations have been made for remaining categories similarly. The summary of calculations is presented in Table 4.

Table 4. Assessment of risk level.

		O1M	S1M	D1M	SRI1M	RLI1M	TRI
1M	1M$_1$	5	4	3	117	299	1344
		4	3	4			
		3	3	1			
	1M$_2$	5	6	5	150		
	1M$_3$	8	4	1	32		
		O2M	S2M	D2M	SRI2M	RLI2M	
2M	2M$_1$	3	3	2	18	90	
	2M$_2$	4	4	2	32		
	2M$_3$	4	10	1	40		
		O3M	S3M	D3M	SRI3M	RLI3M	
3M	3M$_1$	7	4	1	28	395	
	3M$_2$	6	4	5	120		
	3M$_3$	7	5	5	175		
	3M$_4$	6	4	2	48		
	3M$_5$	4	3	2	24		
		O4M	S4M	D4M	SRI4M	RLI4M	
4M	4M$_1$	8	10	7	560	560	

Value of Total Risk Indicator (TRI) in presented production system is 1344 units. Factor from men category of 4M (4M$_1$- Absence of employees) has the highest input on the total risk value. The factors from the 3M category were also crucial. The smallest share relates to the risk factors for material category – 7%. The last stage was the introduction of improvement actions in order to eliminate or minimize risk occurrence. According to Pareto principle, the threshold of 80% was established. The factors that required immediate improvement were related to employees' absences (4M$_3$), errors analysis by assembly operator, (3M$_3$) tester's breakdown (1M$_2$) and assembly line's occupation by engineer (3M$_2$).

Based on presented risk assessment's results, the analyzed organization implemented actions below:

- human resources monitoring system to track employee holidays etc.
- attendance premium

- conducting training for assembly operators. The training focused on the process of analysing errors for each product and the attendees of this training have been documented for further verification
- introduction of work's instruction related to the analysis of errors for various cases
- performing the analysis of errors 'outside' of assembly line by worker in order to minimize losses
- introduction of a rule that an engineer is not allowed to take the assembly line which has production backlogs. Engineers can perform tests or analysis only during production break.

5 Conclusion

Risk management to improve efficiency of processes, is fairly difficult task. Many enterprises use independently developed methods for calculating the risk. However, in many production systems, procedure of risk management is improper or disregarded at all. This article presents the issue of risk management in production systems. It has been done through providing the new, integrated methodology of risk assessment and analysis with regards to the main 4M categories of factors category disturbing the proper production process.

In order to know which area requires improving the most, it is crucial to identify, categorize and establish the probability of occurrence, the severity and detection rate of each risk. In this way, appropriate actions can be applied to certain areas as an attempt to improve them.

Process of risk management should be a standard routine of any organization. Implementation of one-time analysis will not bring any positive effects. The levels of risk are not constant and may change over time. The risk factors decrease, disappear or new threats appear. However, effective risk management leads companies to improve their activities and add value to the organization [14].

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