OPPORTUNITIES AND RISKS OF INTRODUCTING ELECTROGALVANIZING SERVICES EXAMINED ON THE BASIS OF A MANUFACTURING PLANT AND WITH THE EMPLOYMENT OF FMEA

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Abstract

The paper describes the activity of a manufacturing plant, operating in the metal industry. The discussed business entity intends to expand its production scope by applying anti-corrosion coatings to metal components. The studies have been focused on economic aspects related to the implementation of a new department into the plant, risk analysis for the operating business entity and benefits arising from holding own department applying anti-corrosion coatings on metal components. The FMEA method employed in the studies has enabled defect detection in the planned processes and the analysis of factors that may affect the investment. The factors that have been taken into account are environmental effects, implementation methods, machines and equipment necessary for carrying out the investment as well as control measures. During the studies potential project defects and their effects, including class, causes and occurrences have been selected. In the paper general research findings for other organizations within the examined industry have been presented.

Keywords: Application of anti-corrosion coatings to metal components, manufacturing plant, a FMEA, metallurgy, steel

1. INTRODUCTION

The subject-matter of this paper is the risk analysis of introducing a new department to a business entity, characterized by applying anti-corrosion coatings to metal components [1]. The production company under study deals with metalworking and applying paint coatings to metals. Currently, organizations face a dilemma of extending their offer to galvanic services. It is a very time-consuming and demanding investment in financial terms. Also, the impact of galvanic processes on the natural environment and work safety can be very harmful. The implementation of the process of applying anti-corrosive coatings to galvanic elements is a complex activity requiring proper building facilities, but also high qualifications of employees and proper handling of chemical substances. The FMEA analysis aims to show potential disadvantages and threats during the implementation of investments in the company and draw management's attention to the biggest disadvantages and threats.

Galvanic coatings may be delivered during a galvanic bath without the necessity of using external power supply. Metal components are dipped into bathtubs filled with electrolyte, one by one covered with metal connected to a negative pole of the power supply, giving a cathode. An anode consists of plates made of collected metal, which supplement missing metal in the electrolyte [2].

The employment of FMEA (Failure Mode and Effects Analysis) method aims to detect defects at the earliest stage of the process. The FMEA method is based on the analysis of the factors that may affect the examined process and are related to the process methods, accessories, environmental impact as well as determination of control measures [3,4].

The first stage of the FMEA method refers to the selection of operations that should be analyzed and the scope of the analysis that should be established. The number of parts and levels of the method depends on the complexity of the process [5].

The second stage is to stipulate precisely the actions connected with conducting the FMEA. Firstly, potential defects, which may occur in the examined case, need to be identified. After establishing the sequence of events: cause- defect - effect, each defect should be assessed by an integer from the range of 1 to 10, taking into account three criteria: risk - likelihood of occurring defects - cause [6,7].

The last stage of the risk analysis with the use of the FMEA method defines elements, in which changes should be introduced, which aim to reduce the risk of defect occurrence.

2. FMEA

The FMEA describes the process of implementing new services into the manufacturing plant which fundamental activity is metalworking. The metal components produced in the plant undergo electro galvanization processes and subsequently are coated with powder paints. The production line supplemented by own department for delivering anti-corrosion coatings broadens the plant's offer and enhances the position of the business entity on the local market. The analysis of risk factors that refers to new services has been presented below in **Table 1**. The investment performance is based on the construction of a production hall designed for applying anti-corrosive coatings to metal components, administrative procedures related to validation of the undertaking, obtaining funds for the investment, preparing necessary infrastructure and acquiring new customers.

Table 1 FMEA sheet [Own study based 6,7,8]

No.	Process Name	Potential Failure Mode	Potential Effect of Failure	Severity	Potential Causes of Failure	Occurrence	Current Process Controls	Detection	RPN
1. Construction process									
1.	Raising funds for investment performance	Failure to submit documentation on time	Rejecting the application for financial funding	9	Preparing the application without taking enough time	3	Careful control of deadlines	1	27
		Errors in documentation	Rejecting the application for financial funding	9	Preparing the application without employing due diligence	6	Examination of the application by in-house legal department	3	54
			Extending the deadline for raising funds	8	The application supplemented /corrected with required data	4	Including in the construction timetable potential deadline shifts		96
		Too many entities applying for funds	Rejecting the application for financial funding	7	Insufficient argumentation	4	Examination of the application by external counsel	5	140
			Granting some of the applied funds	8	Insufficient funds	2			80
		Granting some of the applied funds	Insufficient funds for investment performance	6		1		3	18

Table 1 - continue

2.	Applying for an investment credit facility	Limited credit capacity	Bank denies granting the credit facility	9	Other company's liabilities	3	Additional collateral	2	54
		Necessity of providing higher own contribution than planned	Postponing the investment in order to obtain the required own contribution	8	Insufficient company's credit capacity	2		7	112
		Long-term credit burden to the company	No chance to apply again for a credit facility for future investments and actions	4	Long-term debt burden	8		8	256
		Changes on the market affecting the entity's activity	Inability of credit repayment	6	Inflation, currency fluctuations etc.	5	---	3	90
			Extended credit repayment period	5	Increase in prices of raw materials and materials necessary for production	4	---	6	120
			Necessity of introducing foreign capital to the business entity	7	Inability of credit repayment	3	---	4	84
3.	Investment performance with the use of own funds	Savings exhaustion	No financial liquidity	8	Necessity of securing credit repayment by equity	3	Acquiring new customers	2	48
			Extending time for investment performance	9	Breaks in investment performance to raise funds for the construction to be continued	5		2	90
			Loss of financial credibility	10	Use of all available funds for investment performance	4		2	80
		Extending time for investment performance	Construction of the electro galvanization plant by competitors	10	Too long time devoted to planning, non-consequential performance	2	Pace of acting when creating the new department	1	20
			Loss of potential customers	10		3		2	60

Table 1 - continue

4.	Construction design preparation	Errors in design	Impact on the structure and arrangement of the hall	8	No adequate design review, no knowledge of construction law	2	Thorough monitoring at every stage of investment performance	2	32
		Design rejected by the Office	Extending the investment performance time, necessity of changes in the design	10	Inadequate location of the building in the plot, the respective land development plan does not allow for investment performance	3		1	30
5.	Obtaining required permits	Receiving a negative decision on building permit	No investment performance	10		3	Verification of the land development plan and particular environmental conditions	1	30
			Postponing the performance of the undertaking	9					27
6.	Facility construction	Location of the building below the level of the surrounding ground around the building	No approval for investment performance	8		1		4	32
		Unfavorable weather conditions	Delays in construction process	8	Investment performance in an unfavorable season of the year. Abnormal weather conditions	5	Execution of the most important construction works in an extremely short period of time, securing other construction actions	2	80
		Subcontractors' delays	Investment deadline delayed	7	Subcontractors' failure to meet contractual terms and conditions	5	Signing contracts with subcontractors putting them under the obligation of completing their works within the declared deadline	2	70
			Increased expenditures related to delays	7	Extending the construction duration period - shortening the profit period	4		3	84
		Equipping the building with necessary technical infrastructure	No adequate technical measures	7	Lack of the required technical measures	3	---	3	63
			Too high purchase costs of technical infrastructure	6	Low competitiveness of companies offering the plant technical equipment	3	Purchase of technical measures abroad	5	90
			Purchase of second-handed technical measures	3	Too high purchase costs of new technical infrastructure	2	Purchase of other technical measures from the companies in liquidation	5	30

Table 1 - continue

7.	Acceptance inspections	Errors during the construction process	Necessity of restoring the building to its original state	10	Ignoring remarks and suggestions of the public administrative bodies and construction law	2	Following precisely the design requirements	5	100
		No adequate wall and floor protection against galvanic substances or baths	Adjustment of the construction infrastructure to essential requirements	6		3		6	108
			Acceptance inspection of the building in delay	9		6			324
		No adequate ventilation systems	Equipping the room with an additional ventilation system	5	Ignorance of air change requirements	6		5	150
			Acceptance inspection of the building in delay	9		2		2	36
		No adequate fire protection	Satisfying necessary fire protection requirements	6	Ignorance of fire protection requirements	3		5	90
			Investment performance postponed	9		5		2	90
		Inadequate sanitary conditions	Satisfying necessary sanitary requirements	4	Ignorance of legal regulations on sanitary conditions	3		5	60
			Investment performance postponed	9		5		2	90
		Objections against OHS conditions	Satisfying necessary OHS requirements	4	Ignorance of OHS regulations and requirements	2	Cooperation with OHS services	5	40
			Investment performance postponed	9		5		2	90
		Objections against environmental protection issues	Satisfying necessary environmental requirements	4	Ignoring remarks and suggestions of the public administrative bodies and environmental protection regulations	2	Following precisely the environmental requirements	5	40
			Investment performance postponed	9		5		2	90

Table 1 - continue

2. OHS conditions									
8.	Infrastructure adjustment	Slippery surface	Slips	1	Workers paying insufficient attention	7	Delivery of slip resistant flooring	8	56
			Falling into galvanic bath tubs	2	Ignorance of OHS regulations	6	Workers paying more attention	3	36
		No adequate ventilation system	Explosive atmosphere forming	9	No adequate extraction ventilation systems	4	Conducting ventilation inspections on a regular basis	4	144
			Emission of hazardous vapors from baths	3		4		4	48
			Work ban	9		4		2	72
		Bathtub damage	Galvanic bath spill out	9	No respect for entrusted equipment	3	Extensive training on OHS, hazardous substances handling. Employment of workers with adequate competences	2	54
			Leakage of hazardous substances		Equipment defects				
		Unintentional mixing of different baths or galvanic sewage	Adverse chemical reactions	9	Workers hold no adequate knowledge of hazardous substances handling	2		2	36
					No adequate training for workers				
		No adequate bath monitoring	Unacceptable hydrogen cyanide concentration at work stations	10	No appropriate measurement tools	3		5	150
					Measurement tools damage	6			300
		No appropriate bath separation	Potential intermingle of baths, vapors and sewage	10	Workers hold no adequate knowledge and training on chemical substances handling	2		6	120
			Explosive atmosphere forming	9		2		5	90
			Direct hazard to workers' health and life	10		2		4	80

Table 1 - continue

9.	Adjustment of rooms	Inadequate bathtub marking	Errors when providing coatings	6	Workers' distractions	3	Precise adjustment of the infrastructure to the OHS, fire protection requirements	2	36
					No due diligence				
					No workplace training				
			Damage to entrusted material	4	Inadequate handling with entrusted material	3		2	24
		No OHS marking	Improper use of baths	4	No knowledge of proper coating	1		3	12
			Inadequate sewage handling	3	Lack of precision and poor sewage handling, no knowledge of sewage handling	2		7	42
			Direct hazard to workers' health and life	9				3	54
10.	OHS trainings	No OHS trainings	Workers not allowed to work	10	Non-fulfillment of the procedures	2	Extensive trainings of workers on OHS, chemical substances handling. Employment of workers who hold adequate competences. Executing the observance of OHS and fire protection regulations by the workers.	3	60
			Hazard to workers' health and life						
			No adequate knowledge of hazards at galvanizing work stations	9	Insufficient trainings for workers, vital issues related to galvanization process and chemical substances handling failed to be discussed			2	36
			No adequate knowledge of the accident procedure	9					36
			Inappropriate chemical substances handling	10					40
			No personal protection equipment employed	10	Workers' lack of care for own health	3	Executing the use of personal protection equipment	6	180
3. Providing services related to electro galvanization									
11.	Order impact	Too late reaction	Loss of potential customer	8	Workers overloaded with other responsibilities. No additional workers for order services	4	Ordering process inspections on a regular basis. Communication process to be improved	7	224
		No information about the order to the relevant department		7		5		3	105

Table 1 - continue

12.	Ordering process analysis	Erroneous decision on production capacity	Failure to deliver the confirmed order	8	Inadequate information flow	1	Improvement of the communication process	1	8
			Loss of customer	8		3		1	24
			Payment of damages	9		1		2	18
		Inadequate information about stocks	Insufficient amount of chemical substances to deliver the order	6		2		3	36
			Loss of customer	9		1		2	18
		No adequate personnel	Shifting workers from other departments	6	Sick leaves/leaves	3	Training for additional workers providing services in galvanizing department	7	126
			No adequately trained workers	10		2			140
		Hiring workers from temporary employment agencies		10				8	160
		Purchase order of missing raw materials	Extended order execution period	6	Increased number of orders at the supplier's	4	Improvement of the communication process. Verification of the suppliers in terms of the quality of products and services	7	168
			Incorrect purchase order distribution	5	Workers' errors	5		6	150
			Raw materials delivered after the deadline	5	Delays in transport	6		4	120
			No raw materials required to deliver the order	5	Insufficient stocks at the supplier's	6		3	90
		No adequate qualitative and quantitative control	Poor quality of the delivered raw materials	3	No quality control department	4		5	60
			Inadequate number of the delivered raw materials		No workers to verify the supplies				

Table 1 - continue

13.	Galvanization	No adequate degreasing of materials	Insufficiently high pH of acid	3	Worker's mistake. Measurement tools errors	4	Quality control of delivered services	5	60
		Errors during digestion process	Too low pH of acid	4		4		6	96
			Too short digestion process	2	Overloading, worker's mistake	4		6	48
		Errors during flux treatment	Inadequate proportion of solution	4	Worker's mistake	2		4	32
		Errors during drying process	Too low temperature of drying	3		2		5	30
		Errors during galvanizing process	Visible zinc drips off on the material	4	Inaccuracy	7		4	112
14.	Aftermarket services	Errors during invoicing process	Incorrectly issued invoice	2	Worker's mistake	7	Review of the generated documentation	9	126
		Errors during warranty services	No adequate aftermarket services	3	Negligence of workers, postponing the galvanization process	6	Quality control of delivered services	8	144
			Too long time in error	6		7		8	336
			Non-acceptance of defects occurred during the galvanization process	6		5		7	210

Table 1 presents all aspects that may affect the process of implementing a new investment to an economic entity. The above table analyzes the individual processes together with the potential type of defect and the result of the defect. The probability of defect occurrence is determined on a scale of 1 to 10. The value of 1 is assigned to an unlikely situation, and 10 to a very likely situation. Details of the value assignment are specified in **Table 2**. Then the reasons for the defect were determined along with the value determination. Also in this case the cause of the defect is determined on a scale of 1 to 10. Value 1 is assigned to the unlikely situation, and 10 to a very likely situation. The details of the value assignment are set out in **Table 3**. The next step is the formulation of preventive measures and the estimation of the detection parameters set out in **Table 4**. The final stage of the FMEA analysis is the assignment of the RPN parameter [6,7].

Table 2 Defining the severity of defect occurrence [Own study based 5,6]

S	Severity	FMEA services/structure
1	None	Unnoticed impact on service delivery
2-3	Minor	Defect is minor and has a marginal impact on customer satisfaction
4-6	Moderate	Average defect, discernible customer dissatisfaction
7-8	Important	Defect that occurs regularly and has a profound impact on customer dissatisfaction
9-10	Extremely important	Extremely important defect that affects further work, safety and is against legal regulations

Table 3 Defining the likelihood of defect occurrence [Own study based 5,6]

O	Likelihood of defect occurrence	FMEA services / structure / process
1	Remote	No likelihood of defect occurrence
2	Very low	Very low chance for a defect to occur. There are single defects and they occur rarely.
3	Low	Low likelihood of occurring single defects
4-6	Moderate	Defects occur on an average basis in low numbers
7-8	High	Defects are fairly frequent.
9-10	Very high	Very high likelihood of defect occurrence.

Table 4 Defining the likelihood of detection [Own study based 5,6]

D	Detection	FMEA services/ structure / process
1-2	Very high	Detection of defects is certain.
3-4	High	The likelihood of detecting defects is very high, the functionality test or control test is applied.
5-6	Moderate	By defect control average detection may be established.
7-8	Low	Defect detection is hindered.
9-10	Very low	Defects are difficult or impossible to detect.

Allocation of the parameters above to **Table 3** allows to define the risk priority number RPN, which is calculated on the basis of the pattern below [6]:

- RPN = Severity (S) * Occurrence (O) * Detection (D)

RPN enables defining hazards that bring the highest risks as well as the hierarchy according which preventive actions should be implemented [6].

FMEA analysis is a method of identifying and preventing problems related to the analyzed process before its implementation. FMEA focuses on preventing defects of the process or product along with increasing the safety of the process, financial safety of the undertaking, work safety or environmental protection. The FMEA analysis is carried out in the process of designing the process or product, to avoid the greatest risks and disadvantages in the implementation phase. FMEA analysis is an important technique for identifying and eliminating potential defects and errors in the process or product. The research was aimed at showing the disadvantages and the threat of introducing a new service for a production enterprise together with an analysis of preventive measures and paying attention to the largest possible errors [9,10]. The value of RPN showed processes at risk of the biggest defects and measures to be taken to eliminate defects and improve the quality of future processes of services or products.

3. CONCLUSIONS

When conducting the analysis the RPN = 100 has been established, below which the preventive actions are not required. In the examined process the highest risk occurs to be the ignorance of aftermarket services, in particular, too long response time whether a warranty repair should be considered or not. Another high risk to the entire investment is the ignorance or non-fulfillment of due diligence procedure when it comes to the adjustment of the plant infrastructure, in accordance with strict construction, environmental, fire protection, occupational health and safety and sanitary regulations. Further risks are contacts with chemical substances. Particularly, inadequate marking of galvanic bathtubs and uncontrollable mixing of substances and sewage. A vital issue for investment performance is also the correct analysis of incoming orders as well as reliable and deft communication directly to the interested people. A crucial factor that determines project success or failure

is the galvanization of metal components. This process requires primarily involvement, accuracy and precision of delivered services.

Based on the analysis, the company should pay attention to work safety and appropriate behavior of employees in dealing with chemicals. During the galvanic process, continuous control and vigilance of both employees and management is necessary. Subsequent procedures for handling orders and guarantees should be developed. The most important is the quick reaction of employees to incoming orders and appropriate actions in the scope of warranty service. Verification of the most important threats to the process will enable the elimination of risk for the investment and will strengthen the security of investments and will determine the success of the economic entity. The next threat to the implementation of the process are staff shortages, including employees on leave or sick leave. Already during the process design process, special attention should be paid to the working conditions together with ensuring the best possible work environment with appropriate incentives. This is to ensure the continuity of work and the satisfaction of the staff with their duties.

Risk analysis was created for a specific company and especially for the introduction of a new service. Based on the conducted analysis, the values included in **Table 1** emerged. The RPN value presented in the **Table 1** defines the greatest hazards for the process under investigation. A detailed analysis of all RPN values above 100 determines the greatest threat to the introduction of a new service. At the same time, when analyzing the results contained in **Table 1**, you can simultaneously create and implement the appropriate preventive measures described in the "Current preventive measures in the process" column. Disregarding the results of risk analysis using the FMEA method may lead to negative effects on the functioning of the entire enterprise and failure to implement the new service.

The FMEA risk analysis itself can be used for different cases. The problem under investigation concerns the implementation of a new service to a manufacturing company. Each risk analysis carried out on the basis of a given problem is individual. Any enterprise that is technologically similar in nature, risk factors may vary and it is not possible to use the risk analysis prepared for entity A for entity B. The impact of risk factors in some aspects may be the same, but if only in terms of personnel or technology will be different. Risk analysis is always created for a specific company or problem to increase the credibility of the conducted research. The scheme of risk analysis using the FMEA method can be used in each individual problem.

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