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THE CONCEPT OF USING FMEA METHOD FOR THE PURPOSE OF SUSTAINABLE MANUFACTURING

6.1 INTRODUCTION

The way companies run their businesses, and in particular the production ones, is important in achieving the goals of sustainable development. In order to meet the increasing expectations of customers, investors and the local community, they are faced with the task of carrying out their operational activities environmentally and socially responsible. As a result, more and more companies are changing their manufacturing processes to become more sustainable. Therefore the practices of eliminating or at least limiting the negative impact of manufacturing processes on society and the environment are unavoidable. The aim of this paper is to draw attention to the possibility of using the FMEA method – Failure Mode and Effects Analysis in the implementation of the concept of sustainable manufacturing.

6.2 THE CONCEPT OF SUSTAINABLE MANUFACTURING

Sustainable manufacturing is an important part of a company's sustainable development which leads to sustainable value creation based on economic, social and environmental performance. The concept of sustainable manufacturing sometimes is mistakenly identified and limited to the so-called "green manufacturing". The term "green manufacturing" usually concerns to production characterized by reduction of energy consumption per unit of production, the use of recycled materials, or the reduction of generated waste. However, when it comes to sustainable manufacturing it is needed an analysis of the production process which takes into account all dimensions of sustainability: economic, social and environmental. Sustainable manufacturing is understood as creation of product, using processes that minimize negative environmental impacts, save energy and resources, are safe for employees, communities and consumers, and are economically – sound [1].

Taking into account the assumptions of sustainable manufacturing, manufacturers ensure that their business is responsible and does not threaten the environment and potential customers. Good practices for sustainable manufacturing rely on the use of alternative energy sources (solar, wind, and biodegradable fuels) in

the production process. Another important aspect is the desire to reduce material consumption and energy consumption, i.e. the efficiency of resource use. In sustainable manufacturing the attention is paid also to the importance of the human factor in the production process. Fair wages, humanitarian planning, safe working conditions are part of the process of creating sustainable products. In addition, manufacturers should ensure that any outsourced service fulfils the same conditions and requirements as the parent company. The result of the sustainable manufacturing process should be a fully recyclable product as to be a raw material for the production process of a new product. The life cycle of such a product is defined as from cradle to cradle [6]. It should be borne in mind that specific operational activities will always depend on the technology used in the manufacturing process and on the specific nature of each industry.

Summarizing, sustainable manufacturing refers to creating safe and environmentally friendly products throughout their lifecycle, using for this purpose processes functioning in a decent and safe for employees conditions that will reduce material and energy consumption, emissions and increase re-usability of materials or waste while taking into account the impact of these processes and products on society and the financial performance of a company.

6.3 FAILURE MODES AND EFFECTS ANALYSIS

Failure Modes and Effects Analysis (FMEA) is a systematic approach to identify potential defects that arise in the design, manufacturing, assembly or operations. The first uses of FMEA occurred in the 1960s in the space industry, then in the 1970s in the military industry and then in the automotive industry. Currently the method is widely used in various processes not only manufacturing but also in services. The term failure modes used in the method name is widely interpreted and refers to any undesirable states in the analyzed system. The undesirable states may be any errors, malfunctions, failures incompatibilities, in particular those that may affect the customer, both potential and actual. Effects analysis refers to the study of consequences resulting from the occurrence of these undesirable states. Identified defects are the subject to prioritization depending on how serious their consequences are, how often they occur and how easy it is to detect them. The purpose of the FMEA is to take steps to eliminate or reduce undesirable states, starting with those with the highest priority. Analysis of the causes and effects of the defects also serves to document the current state of the art and the actions taken to minimize the risk of adverse events that may be used in the process of continuous improvement of the product/process [7].

The prioritization of undesirable states is done using a risk priority number (RPN). The RPN determines the level of risk associated with a particular undesirable condition in the system which is being analyzed. The value of the RPN is calculated according to the following formula:

$$RPN - S \times O \times D \tag{6.1}$$

where:

- S is the significance of the defect/undesirable state,
- is the probability of occurrence of the defect,
- D is the possibility of detection of the defect.

Each parameter can take a scale from 1 to 10 (see Table 6.1).

Table 6.1 Criteria of severity, occurrence and detection ratings

Severity [S]		Occurence [O]		Detection [D]	
1	meaningless	1	negligible	1	very high
2-3	low	2-3	occasional	2-5	high
4-6	moderate	4-6	moderate	6-8	moderate
7-8	high	7-8	high	9	low
9-10	very high	9-10	very high	10	accidental

Source: [4]

The risk level can be a maximum of 1000. In practice, it is arbitrarily determined the limits of this index, which can be defined as the level of acceptability of risk. It is often assumed that value of RPN less than 120 means an acceptable level of risk for the defect. In this case, there is no need to take preventive actions [4].

FMEA analysis consists of two steps. In the first stage, potential defects, undesirable states are identified and parameters of significance, frequency of occurrence and possibilities of detection are estimated. Then it is calculated the risk priority number for each identified defect which enable to prioritize them. In the second stage, preventive measures are defined. Once these measures are taken, the RPN is recalculated and the cycle in the second stage of the analysis is repeated until an acceptable level of risk is achieved [2]. The results of the FMEA analysis serve as a basis for making changes in the design or manufacturing processes aiming at reducing the risk of defects identified as critical [5]. If it is not possible to completely eliminate the cause of the failures, actions are taken to increase their ability to detect them or reduce the negative impact of their occurrence. Implementation of the recommended corrective actions should be continuously monitored and their effects verified.

In this paper, the author draws attention to the possibility of using the FMEA method to improve processes in accordance with assumptions of the concept of sustainable manufacturing. The modification of the FMEA method is based on the fact that the potential failures/undesirable states of the process are analyzed taking into account the three dimensions of sustainable development.

Sustainable manufacturing practices are designed to provide responsible, environmentally friendly, safe for employees and community production. To make the manufacturing processes more sustainable, it is important to analyse the processes of the early stages of the product life cycle. The process selected for further analysis in this article is the procurement process for new launch of production in the automotive industry.

6.4 THE EXAMPLE OF USING MODIFIED FMEA METHOD IN PROCUREMENT PROCESS FOR NEW LAUNCHES

In the automotive industry, the introduction of a new product generally requires changes in production technology, changes in the organization of the production line, etc. (we are dealing with a sequence: new product – new technology – new work organization and new organization of production) [3]. The procurement process for new launches may be crucial for sustainable manufacturing due to a long cycle of development works in the automotive industry which are far ahead of the production launch. As a result, the decisions made in the procurement process for a new production launch will affect future manufacturing processes. Therefore it is important to take into account the assumptions of sustainable manufacturing at this stage. During the analysis of the selected process, a cross-functional team should be selected consisting of various experts involved in the process (e.g. engineering, procurement, product development, environment, safety) to fill in the sustainable manufacturing FMEA form (see Table 6.3). For an in-depth analysis of the process, firstly it should be determined the scope of the process, its inputs, outputs, suppliers and stakeholders (see Table 6.2).

In the selected for the analysis process (procurement of new launches) potential undesirable states have been identified, taking into account the three dimensions of sustainable development: economic, social and environmental.

Table 6.2 Identification of procurement process for a new launches

SUPPLIERS	INPUT	PROCESS	OUTPUT	STAKEHOLDERS
• construction department • sales department • suppliers of materials, machinery and equipment	• list of materials, machinery and equipment, • project data: quantity (pcs), project duration, milestones (start of production, prototype dates and first batch), • inquiries, • criteria for evaluating suppliers.	Procurement process (production and non-production procurement) for new launches	• list of suppliers with specified trading conditions, • first production batch, • purchased machinery and equipment	• owners, • executives, • environment, • production, engineering, • quality department, • potential suppliers, • customers, • local community.

Source: own

In the social dimension, aspects related to both employees and local communities have been identified. Following a sample analysis, the limit of the RPN index was set at 120. For all those identified in the procurement process, undesirable states with a RPN of more than 120 it was suggested improvement actions. Five such undesirable states have been identified, two relating to economic aspects and three to social aspects. For identified failures, improvements were proposed, and after their implementation an acceptable level of risk was achieved (see Table 6.3).

Table 6.3 Modified FMEA form with sustainability aspects – the example of the procurement process for new launches

PROCESS NAME: PROCUREMENT PROCESS (PRODUCTION AND NON-PRODUCTION PROCUREMENT) FOR NEW LAUNCHES													
ASPECTS	**UNDESIRABLE STATES**	**EFFECTS**	**S**	**CAUSES**	**O**	**DETECTION**	**D**	**RPN**	**IMPROVEMENT ACTIONS**	**S**	**O**	**D**	**RPN**
ECONOMIC	*Too high price of purchased materials in relation to design assumptions*	*Loss for the enterprise, uncompetitive product in terms of price*	*5*	*Selection of uncompetitive suppliers*	*4*	*The principle of choosing suppliers (min 3 offers)*	*3*	*60*					
				Ineffective trade negotiations	*5*	*lack*	*10*	*250*	*Cost estimator, market test, auctions*	*5*	*2*	*2*	*20*
	Failure to meet production start date	*Customer loss, fines, loss of image*	*6*	*No supervision over the supplier*	*6*	*Launching in accordance with APQP*	*2*	*72*					
				Incorrect start time schedule information	*4*	*Launching in accordance with APQP*	*2*	*48*					
	Non-fulfillment of technical requirements by the product	*Financial penalties, loss of image, customer dissatisfaction, lower morale of the staff involved in the project*	*8*	*Incorrect specification*	*4*	*TFC*	*2*	*64*					
				Incorrect process	*3*	*SPC*	*2*	*48*					
				Low quality materials	*3*	*Control plan*	*4*	*96*					
				Human errors	*4*	*Control plan, training*	*4*	*128*	*Employee training, Poka – Yoke*	*8*	*2*	*4*	*64*
SOCIAL: EMPLOYEES	*Purchased machines do not meet safety requirements*	*Danger to life and health of employees, penalties resulting from falling to ensure safety in the workplace*	*10*	*Incorrect specification of machines*	*6*	*Risk assessment*	*3*	*180*	*Employee training, Poka – Yoke; lesson learned*	*10*	*3*	*2*	*60*
				Defective product	*4*	*Technical acceptance of the machine*	*2*	*80*					
	Harmfulness / toxicity of purchased materials	*Danger to life and health of employees, penalties resulting from falling to ensure safety in the workplace*	*10*	*Wrong specification*	*5*	*Technical acceptance*	*2*	*100*					
				Inappropriate materials/ substances used by the supplier	*2*	*IMDS*	*3*	*60*					
	Selection of suppliers who do not meet safety standards	*Stopping of production, delays in delivery due to increased absence, accidents among supplier's employees*	*10*	*Lack of sufficient knowledge among the procurement department staff*	*3*	*Supplier evaluation procedure/criteria*	*3*	*90*					
				Human errors	*5*	*Supplier evaluation procedure/criteria*	*3*	*150*	*Employee training, Poka – Yoke; lesson learned*	*10*	*3*	*3*	*90*
SOCIAL: LOCAL COMMUNITY	*Lack of inclusion of local suppliers in the project of new launch*	*Lack of local business development, increased transportation nuisance*	*3*	*Lack of discerning of local market*	*3*	*lack*	*10*	*90*					
				No policy supporting local suppliers	*9*	*lack*	*10*	*270*	*Developing a procurement policy that takes into account local communities*	*3*	*5*	*6*	*90*
ENVIRONMENTAL	*Selecting suppliers that do not meet environmental standards*	*Environmental hazards, image loss, monetary penalties, employee health hazards*	*6*	*Lack of sufficient knowledge among the procurement department staff*	*3*	*Supplier evaluation procedure / criteria*	*3*	*54*					
				Human errors	*5*	*Supplier evaluation procedure/criteria*	*3*	*90*					

TFC – Team Feasibility Commitment; **SPC** – Statistical Process Control; **IMDS** – International Material Data System

Source: own

6.5 CONCLUSIONS

In this paper, the author draws attention to the possibility of using the FMEA method to improve processes in accordance with the concept of sustainable manufacturing. The proposed modification of FMEA method on the example of the procurement process for new launches has allowed to determine the impact of the process on the economic, environmental and social outcomes as well as to identify the potential risks associated with functioning of the process.

Realization of the FMEA method requires the involvement of an interdisciplinary team. Therefore, the additional benefit of using its extended version may be the raise of awareness among employees concerning the impact of the company's processes on economic, social and environmental performance. In turn, a change in mentality among employees will contribute to building an organizational culture that fosters further change towards more sustainable manufacturing.

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Abstract: *Sustainable manufacturing is to ensure that cost-effective manufacturing processes do not endanger the environment, are implemented in a way that is safe for life and health of employees and the public. The question then arises of how to improve manufacturing processes to make them more sustainable? Such a question cannot be answered unequivocally. The author draws attention to the possibility of using for that purpose FMEA (Failure Mode and Effects Analysis) method, which aims to identify potential defects in the process/product and then eliminate them or minimize the risks associated with them. In the article it will be proposed modification of this method for using it in the process of sustainable manufacturing.*

Key words: *sustainable manufacturing, failure mode and effects analysis, FMEA, manufacturing launch, purchasing*

KONCEPCJA WYKORZYSTANIA METODY FMEA DLA POTRZEB ZRÓWNOWAŻONEGO WYTWARZANIA

Streszczenie: *Zrównoważone wytwarzanie polega na zapewnianiu, że opłacalne ekonomicznie procesy wytwórcze nie zagrażają środowisku naturalnemu, są realizowane w sposób bezpieczny dla zdrowia i życia pracowników oraz społeczeństwa. Powstaje zatem pytanie w jaki sposób usprawniać procesy wytwarzania aby uczynić je bardziej zrównoważonymi? Na tak postawione pytanie nie sposób odpowiedzieć jednoznacznie. Autorka artykułu zwraca uwagę na możliwość wykorzystania w tym celu metody FMEA (Failure Mode and Effects Analysis), której celem jest identyfikowanie potencjalnych wad produktu/procesu, a następnie ich eliminowanie lub minimalizowanie ryzyka z nimi związanego. W artykule zaproponowana zostanie modyfikacja tej metody dla zastosowania jej w procesie zrównoważonego wytwarzania.*

Słowa kluczowe: *zrównoważone wytwarzanie, analiza przyczyn i skutków wad, FMEA, nowe uruchomienie produkcji, zakupy*