

A Sustainable Development Evaluation Card for a Manufacturing Company

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Abstract: Sustainable development (SD), in production, is possible when the company's management has access to data and information, the analysis of which allows the level of SD to be assessed. The use of information technologies enables enterprises to effectively manage resources through comprehensive and integrated solutions, matched to the specific needs of the enterprise. The article proposes a Sustainable Development Evaluation Card for a manufacturing company, which consists of the following elements: (1) SD goals, (2) SD indicators, (3) Analytic Hierarchy Process method, (4) ERP system functionality, (5) reference values of SD indicators, (6) level of SD, (7) recommended actions for SD. The usability of the proposed solution is shown, using as an example a real-life, production company as a case study. Copyright © 2020 IFAC

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1. INTRODUCTION

The current trend in understanding information systems is moving from the purely technological, in favour of a system approach, as this is the only way for a system to control functions in an organisation. Information systems enable enterprises to effectively manage resources through comprehensive and integrated solutions, matched to the specific needs of the enterprise. An example of the above are Enterprise Resource Planning systems (ERP), which are "a formal representation of a certain image of an organisation - its functional model" (Haddara 2014). The article adopts the application of the ERP functionality in terms of acquiring the data and information for the assessing the level of sustainable development in manufacturing enterprises.

The sustainable development programmes adopted, indicate the need to implement systemic changes. Meeting the challenges posed by Sustainable Development (SD) is expensive, at the same time, it requires the development of effective strategies, in order to achieve the goals. In this paper the SD have been narrowed to the production area. Therefore, the implementation of SM, in manufacturing enterprises, aims at ensuring that manufacturing resources are used rationally, both in terms of the economic aspects and as regards environmental protection, while simultaneously considering the consequences for all interested parties [Huang et al.2018].

The manufacturing company is looking for a solution to assess the level of sustainable development in the enterprise; this will allow to obtain knowledge regarding the level of SD in the enterprise, thanks to the data and information obtained from the ERP system.

So, we are developing a Sustainable Development Evaluation Card (SDEC) for a Manufacturing Company. Thus, motivated by the need to collect and store data and information regarding the SD, the SDEC, based on the Analytic Hierarchy Process method, is presented. In addition, we define in our approach, the needs of the company's management in terms of the expected level of SD within a company.

2. SUSTAINABLE DEVELOPMENT (SD) IN A MANUFACTURING COMPANY

Production is an integral part of society and plays an important role in shaping and developing the economy. The concept of production can be defined as the process of processing materials into a useful, added value in the form of a specific product, by carrying out one or more operations (Shibin, 2016). According to the above definition, when looking for improvement in production, attention should be focussed on three key elements: resources, processes and products. Enterprises are increasingly leaning towards sustainable production, which is part of sustainable development, broadly understood. The managers of manufacturing companies should increase their attention to research in the field of sustainable production, because it is one of the goals, is considered as an overarching sustainable development priority (Moldavska and Welo 2019).

In recent years, SD strategy in manufacturing companies, has focussed primarily on the life cycle of a product. In the United Nations Programme on the environment, there is a definition that thinking about a product, in the context of its

life cycle. The environment, society and the economy are three, acceptable elements of SD (Carter and Easton, 2011). Nowadays many researchers indicate the need for further research on practices and tools supporting the objectives of the SD in manufacturing companies (Bhatt et al. 2020; Mennega et al. 2019; Huang et al. 2018).

Sustainable development measures at enterprises are subject to constant monitoring and evaluation. Key SD monitoring tools include indicators which depict the essence of the SD concept in a measurable way. The key indicator in the area of sustainable manufacturing and consumption is resource efficiency. One of the common solution is to implement in the enterprise a management system in line with the 14001 norm. It consists of guidelines on an environmental management system. The main task of the norm is to support environmental protection, considering the social and economic needs that are in line with SD. However, the norm does not include necessary requirements but only recommendations to implement commitments presented in an environmental policy.

The available literature on the subject indicates the need to consider production processes from the product design stage, through production, to the logistics stage. Sustainable development in the production phase should be analysed in three areas (Shibin 2016):

Production processes: product design and production processes, selection of materials, use of resources.

Product durability during use: generation of product emissions into the environment, ease of maintenance, etc.

Development from the re-cycling and logistics point of view: the possibility of re-using materials, re-cycling, and easy dismantling.

Our SDEC for a manufacturing company is defined according to those three areas. On the other hand, we assume that the implementation of the proposed card is possible only in such enterprises that use the ERP system. ERP systems enable the collection of data and information of all departments and functions at a company in one computer system (Shen et al. 2016). The implementation and use of an ERP system facilitates reaching the needed data and information for obtaining the values of SD indicators.

For the purpose of this article, the specification of implementing and using an ERP system has been narrowed down to a definition of the system functionalities with the aim to acquire the data and information for SDEC.

3. SUSTAINABLE DEVELOPMENT EVALUATION CARD FOR A MANUFACTURING COMPANY

Based on an analysis of the literature on the subject and work carried out in manufacturing companies, the SDEC was developed for a manufacturing company, in terms of using the ERP system, which consists of the following elements: (1) SD goals, (2) SD indicators, (3) Analytic Hierarchy Process method, (4) ERP system functionality, (5) reference values of SD indicators, (6) level of SD, (7) recommended actions for SD (Table 1):

Table 1. SDEC

SD Area	Defined SD indicators using AHP method	ERP system functionality	Reference values of SD indicators	Level of SD	Recommended actions for SD
Production processes	SD_{pp}	E_{pp}	vSD_{pp}	G/A/BA	rSD_{pp}
Product durability	SD_{pd}	E_{pd}	vSD_{pd}	G/A/BA	rSD_{pd}
Product development	SD_{pv}	E_{pv}	vSD_{pv}	G/A/BA	rSD_{pv}

where:

$SD_{pp} = \{SD_{pp1}, SD_{pp2}, \dots, SD_{ppn}\}$, where $n \in \mathbb{N}$ – set of SD indicators using AHP method in the production processes area

$SD_{pd} = \{SD_{pd1}, SD_{pd2}, \dots, SD_{pdm}\}$, where $m \in \mathbb{N}$ – set of SD indicators using AHP method in the product durability area

$SD_{pv} = \{SD_{pv1}, SD_{pv2}, \dots, SD_{pvq}\}$, where $q \in \mathbb{N}$ – set of SD indicators using AHP method in the product development area

$E_{pp} = \{E_{pp1}, E_{pp2}, \dots, E_{ppt}\}$, where $t \in \mathbb{N}$ – set of the ERP functionalities, that enable automatic acquisition of data and information for calculating the value of SD_{pp}

$E_{pd} = \{E_{pd1}, E_{pd2}, \dots, E_{pdl}\}$, where $l \in \mathbb{N}$ – set of the ERP functionalities, that enable automatic acquisition of data and information for calculating the value of SD_{pd}

$E_{pv} = \{E_{pv1}, E_{pv2}, \dots, E_{pvj}\}$, where $j \in \mathbb{N}$ – set of the ERP functionalities, that enable automatic acquisition of data and information for calculating the value of SD_{pv}

$vSD_{pp} = \{vSD_{pp1}, vSD_{pp2}, \dots, vSD_{ppn}\}$, where $n \in \mathbb{N}$ – set of the reference values of SD_{pp} indicators

$vSD_{pd} = \{vSD_{pd1}, vSD_{pd2}, \dots, vSD_{pdm}\}$, where $m \in \mathbb{N}$ – set of the reference values of SD_{pd} indicators

$vSD_{pv} = \{vSD_{pv1}, vSD_{pv2}, \dots, vSD_{pvq}\}$, where $q \in \mathbb{N}$ – set of the reference values of SD_{pv} indicators

G/A/BA – level of SD within a manufacturing company:
 GOOD/AVERAGE/BELOW AVERAGE

$rSD_{pp} = \{rSD_{pp1}, rSD_{pp2}, \dots, rSD_{ppq}\}$, where $q \in \mathbb{N}$ – set of the recommended actions for SD in a manufacturing company in the production processes area

$rSD_{pd} = \{rSD_{pd1}, rSD_{pd2}, \dots, rSD_{pds}\}$, where $s \in \mathbb{N}$ – set of the recommended actions for SD in a manufacturing company in the product durability area

$rSD_{pv} = \{rSD_{pv1}, rSD_{pv2}, \dots, rSD_{pvp}\}$, where $p \in \mathbb{N}$ – set of the recommended actions for SD in a manufacturing company in the product development area

Each element of the SDEC is strictly defined:

(1) The objectives of SD:

The first element of the card includes a definition of the objectives in the defined areas of SD. The following objectives in SD areas are defined based on the Global Reporting Initiative (GRI) and Agenda 2030 guidelines.

In the SD area: production processes: reduction energy consumption, reduction pollution to environment, improve

quality of the process, reduction material intensity and energy consumption to manufacturing process, production cost, increasing innovation, recycling, reduction of the amount of waste produced.

In the SD area: production durability: High quality of products: prevention of downtime, closs lopp materials, improve reliability of the product, reduction of failure rate of product.

In the SD area: product development: customer satisfaction, employee satisfaction. decent working conditions, protection of the workplace, care about organizational image, socially and creatively cost-effective manufacturing, increasing society benefits without compromising of future generations, manufacture of safe goods.

(2) SD indicators

For each SD area the SD indicators (Table 2, Table 3, Table 4) based on (Global Reporting Initiative, Moldavska et al.2019; Moldavska et al.2016; Rajak et al. 2015; Singh et al.2016; Shibin 2016; Wass et al. 2014) are defined.

Table 2. Indicators of achieving the objectives of SD in a manufacturing company - the area of production processes

The objectives of SD in the area of production processes	Defined SD indicators
Reduction energy consumption	SD _{pp1} - energy consumption (Waas et al., 2014)
Reduction pollution to environment	SD _{pp2} - total air emissions/ during the production/during the distribution. (Waas et al., 2014)
Improve quality of the process	SD _{pp3} - Overall Equipment Effectiveness
Reduction material intensity and energy consumption to manufacturing process	SD _{pp4} - Resources productivity
Production cost	SD _{pp5} - Organization's income (Wight, 2010)
Increasing innovation	SD _{pp6} - Technological progress (Wight, 2010)
Recycling, reduction of the amount of waste produced	SD _{pp7} - Level of waste recycling

Table 3. Indicators of achieving the objectives of SD in a manufacturing company - the area of production durability

The objectives of SD in the area of production durability	Defined SD indicators
High quality of products	SD _{pd1} - quality of product compared to competitors (Waas et al., 2014)
	SD _{pd2} - Number of defective products
Prevention of downtime	SD _{pd3} - Number of defective products
Closs lopp materials	SD _{pd4} - Re-utilisation waste
Improve reliability of the product	SD _{pd5} - Failure rate of product in use (Wight, 2010)

Reduction of failure rate of product	SD _{pd6} - Repair rate of product
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Table 4. Indicators of achieving the objectives of SD in a manufacturing company - the area of product development

The objectives of SD in the area of product development	Defined SD indicators
Customer satisfaction	SD _{pv1} - Customer satisfaction (Wight, 2010)
Employee satisfaction	SD _{pv2} - Employee satisfaction (Wight, 2010)
Decent working conditions	SD _{pv3} - Range of benefits for workers (Wight, 2010)
Protection of the workplace	SD _{pv4} - Safety incidents
Care about organizational image	SD _{pv5} - Implementing the order on time
Socially and creatively cost-effective manufacturing	SD _{pv6} - Cost of product compared to similar products (Waas et al., 2014)
Increasing society benefits without compromising of future generations	SD _{pv7} - Risk management related to climate-relatede (Waas et al., 2014)
Manufacture of safe goods	SD _{pv8} - Hours of safety training per employee (Wight, 2010)

(3) AHP method

The third element of the method is the selection of key indicators using the AHP method. The application of the AHP method consists in decomposing a given issue into simpler components which then undergo pairwise comparison, in this way it facilitates choosing the best solution from the selected alternatives (Satty 1990).

The use of the AHP method facilitates the decision making process in case when the selection of chosen criteria is not necessarily measurable (social, environmental, economic). The application of the AHP method consists in decomposing a given issue into simpler components which then undergo pairwise comparison, in this way it facilitates choosing the best solution from the selected alternatives. The AHP method is successfully applied to qualitative as well as quantitative data (Rajak and Shaw 2019). Finding the best solution through applying the AHP method consists in constructing a pairwise comparison matrix. The matrix takes the dimensions of NxN, where N stands for the number of components assigned to a given level.

The procedure for determining local weights is launched, which is done in the following way: 1) determine the sum of evaluation values in each column; 2) each of the obtained evaluation needs to be divided by the number of components. The sum of the obtained weights should equal 1.0. On the basis of the obtained weights, materiality ranks of selected alternative are indicated. In order to check the correctness of calculations, after obtaining the weights values one needs to

measure comparison consistency which represents proportionality of preferences. For this purpose, a consistency index (CI) is constructed, followed by consistency ratio (CR). It is assumed that comparison is consistent where $CR \leq 10\%$ (for $n \leq 5$). If the consistency ratio is not accepted, the whole or a part of comparison needs to be repeated.

(4) ERP system functionality

The fourth element of the SDEC determining the functionality of the ERP system in the context of support for monitoring the level of SD in the manufacturing enterprise. This stage consisted in determining the company's actions that are supported by an ERP system and its functionality was indicated.

(5) Reference values of SD indicators

The fifth element of the SDEC consists in defining reference values for the indicators in the three SD areas defined. The indicated indicators' values are compared with the established reference values of the indicators. If the required reference values are not met, the system indicates recommended actions to support the implementation of the objectives in the area of SD.

(6) Level of SD and (7) recommended actions for SD

According to comparing the established reference values of the SD indicators and their required reference values the level of SD within a manufacturing company is established and the finally the recommended actions for SD are given.

4. A CASE STUDY

A developed SDEC was implemented in a Polish manufacturing company. The production company examined, specialises in steel processing and has 19 employees. The company operates a two-shift system. The study used data obtained from the implementation of an order for 3,000 pieces of steel sheet elements with a thickness of 5 mm each.

In the first element of the SDEC, the objectives of SD for the enterprise were examined and their implementation SD indicators were adopted. The adopted goals were assigned to three defined areas of SD according to Table 2, Table 3, Table 4.

The third element of our approach consisted in the selection of SD key indicators, using the AHP method in three defined areas.

By the use the AHP method the company's management is appointed as the expert for designing a matrix for paired comparison and calculating weights for individual alternatives. As an example, the use of the AHP method for the area of production durability is shown (Table 5):

Table 5. Pairwise comparison matrix - the area of product durability

SD_{pd}	SD_{pd1}	SD_{pd2}	SD_{pd3}	SD_{pd4}	SD_{pd5}	SD_{pd6}	SUM
SD_{pd1}	1.0	0.5	0.5	0.5	0.5	1.0	4.0
SD_{pd2}	2.0	1.0	1.0	0.5	1.0	2.0	7.5
SD_{pd3}	2.0	1.0	1.0	1.0	2.0	2.0	9.0
SD_{pd4}	2.0	2.0	1.0	1.0	2.0	2.0	10.0
SD_{pd5}	2.0	1.0	0.5	0.5	1.0	2.0	7.0
SD_{pd6}	1.0	0.5	0.5	0.5	0.5	1.0	4.0
SUM	10.0	6.0	4.5	4.0	7.0	10.0	41.50

The experts in the company (members of the company's management board) assessed the validity of the adopted indicators. Weights were calculated for individual variants on the basis of Table 5. The obtained results are presented in Table 6 and Table 7.

Table 6. Matrix of pairwise comparisons - determination of weights for individual variants - the area of product durability

SD_{pd}	SD_{pd1}	SD_{pd2}	SD_{pd3}	SD_{pd4}	SD_{pd5}	SD_{pd6}	SUM
SD_{pd1}	0.10	0.08	0.11	0.13	0.07	0.10	0.59
SD_{pd2}	0.20	0.17	0.22	0.13	0.14	0.20	1.06
SD_{pd3}	0.20	0.17	0.22	0.25	0.29	0.20	1.32
SD_{pd4}	0.20	0.33	0.22	0.25	0.29	0.20	1.49
SD_{pd5}	0.20	0.17	0.11	0.13	0.14	0.20	0.95
SD_{pd6}	0.10	0.08	0.11	0.13	0.07	0.10	0.59

Table 7. Ranking of variants adopted - the area of product durability

Indicator	Weight	Priority
SD_{pd1}	0.10	4
SD_{pd2}	0.18	3
SD_{pd3}	0.22	2
SD_{pd4}	0.25	1
SD_{pd5}	0.16	4
SD_{pd6}	0.10	5
SUM	1.000	-

In the next stage of the AHP method, the compatibility of the obtained comparisons was measured by determining the CI coefficient, followed by the CR coefficient.

Table 8. Determining the inconsistency index - the area of product durability

Indicator	Sum of rating	Weight	λ_{max}
SD _{pd1}	10.0	0.10	0.98
SD _{pd2}	6.0	0.18	1.1
SD _{pd3}	4.5	0.22	0.99
SD _{pd4}	4.0	0.25	0.99
SD _{pd5}	7.0	0.16	1.10
SD _{pd6}	10.0	0.10	0.98
SUM			6.12

So, the consistency index for the area of product durability is: 0.02 and consistency ratio (CR): 1.6%. The resulting CR<10% indicates that the comparison logic was maintained when comparing items. Using the AHP method, the importance of indicators for the areas: production processes and product development was also obtained. The Management Board of the company examined, adopted the role of ‘expert’.

The following SD key indicators were selected (Table 9).

Table 9. The selected indicators for achieving SD goals in a manufacturing company

The objectives of SD	Defined SD indicators	Data and information source/ ERP system functionality
Production processes		
Reduction in energy consumption	SD _{pp1} - energy consumption	Manufacturing
SD _{pp3} - Overall Equipment Effectiveness	SD _{pp3} - Overall Equipment Effectiveness	Manufacturing
Production durability		
Prevention of downtime	SD _{pd3} - Number of defective products	Warehouse management
Product development		
Customer satisfaction	SD _{pv1} - Customer satisfaction	CRM
Decent working conditions	SD _{pv3} - Range of benefits for workers	HR and Payroll

Next, the values of SD indicators for the defined class of manufacturing enterprises to which the analysed enterprise belongs was found in the document Statistical Yearbook of Industry Poland (2018).

Finally, according to Table 1, the SDEC for manufacturing company were defined:

Table 20. SDEC

SD Area	Defined SD indicators using AHP method	ERP system functionality	Reference values of SD indicators	Level of SD	Recommended actions for SD
Production processes	SD _{pp1} = 26141 kWh*	Manufacturing	-	BA	rSD _{pp11} rSD _{pp12}
	SD _{pp3} = 55,5%	Manufacturing	85%	BA	rSD _{pp31}
Product durability	SD _{pd3} = 25,8%	Warehouse management	5%	BA	rSD _{pd31} rSD _{pd32}
Product development	SD _{pv1} = 92%	manual	90%	G	-
	SD _{pv3} = 0	HR and Payroll	0	G	-

where:

*the period over the last six months has been adopted

- rSD_{pp11} - control of the efficiency and performance of machines and equipment
- rSD_{pp12} - implementing the intelligent meters
- rSD_{pd31}- regular screening and reviews
- rSD_{pd32}- servicing, repair and maintenance planning

The proposed approach allows an increase in efficiency of the conducted activities and their control in the area of SD within a manufacturing company. Moreover, the indicators and their weights were developed with the application of the AHP method, whose universality and practicality allows for a simple modification of data as well as extending the model with new criteria.

The proposed solution enables managers to control the undertaken activities in real time, reduce costs, save resources and energy, implement an environmental policy, and constitutes a database for further actions.

5. CONCLUSIONS

The concept of the Sustainable Development Evaluation Card for a Manufacturing Company, presented, is an innovative

and universal tool to support the implementation and monitoring of the objectives of SD in a manufacturing company. The SDEC uses the functionalities of the ERP system, implemented in the company. This solution significantly reduces the time taken up for the collection of data and information and also allows data to be verified in real time. Comparison of the data, obtained from the ERP system, with reference values of SD indicators, thus indicating the current level of achievement of the objectives of SD. The verification of values allows recommended actions to be assigned to a given area and indicates the way forward; this, in turn, enables the expected values of the indicators, to be achieved.

The SDEC implementation in manufacturing company enables constantly monitoring the progress of provided corrective activities and practices in the field of SD. As with all studies, this study owns up to the limitation which further research should be able to overcome. Our approach requires very complex analytical work and adapting the model to the specifics of a given manufacturing enterprise. Therefore, it will be useful to provide further research to formalize the proposed approach for a given class of manufacturing enterprises.

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