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SPECIAL SECTION

Sustainable Business Model integrated with the Enterprise Resource Planning system: SBM-ERP

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Abstract. Increasing the role of sustainable production benefits in transforming manufacturing towards the sustainable organisation. The proposed model integrates two dimensions, namely, the Sustainable Business Model (SBM) and the Enterprise Resource Planning (ERP) system, and defines it as the SBM-ERP. This paper focuses attention on determining SBM-ERP based on the literature research, Fuzzy Analytical Hierarchy Process (F-AHP) method and the results of the analysis on the experiences with the implementation of the ERP system in manufacturing. It was determined that the proprietary approach allows the company's sustainable manufacturing activities to be organised and monitored, based on real-time data and information, as updated and included in the ERP system. We also emphasized the practicality of the proposed approach for managers of manufacturing companies with an implemented ERP system.

Key words: assessment of sustainability; Enterprise Resource Planning (ERP) system; Polish manufacturing company; case study.

1. INTRODUCTION

Sustainability is an integration of institutional, economic, social, and environmental dimensions [1]. In the literature, interest in the business model linked to the context of sustainability has increased greatly in recent years [2]. The main objectives of the Sustainable Business Model (SBM) are to create a competitive advantage by improving the value as perceived by the customer while contributing to the sustainable development of a company [3]. In order to reach a higher level of sustainability, manufacturing must change its business models to SBM [4]. Moreover, considering the necessity to transform an enterprise, in line with the Fourth Industrial Revolution, the assessment of sustainable development should be integrated with the information systems applied within a company. Production is now transitioning to cyber-physical production systems (CPPS) [5]. It is also stated that information systems are very important for companies in the context of increasing the digitalisation of their manufacturing operations [6]. Therefore, the first element of transforming an organisation into an SBM may be to design new functionalities in information systems supporting the continuous assessment and monitoring of sustainable development. So, we are searching for an innovative approach to building SBM for manufacturing, this includes integrating the Enterprise Resource Planning (ERP) system and assessing the sustainability (SA) of a manufacturing company; it may also be incorporated into SBM literature and practice. The ERP system is treated as software that works to integrate business processes and support the management within a company [7–9]. ERP systems consist of many applications, e.g., customer relationship management (CRM) to Business Intelligence (BI) [10]. The authors provide research on the small and medium enterprises sector (SMEs), due to the fact that the implementation of SD in SMEs is still at a lower level than in larger companies [11]. An example of the integration of the ERP system and sustainable production is a roadmap for implementing the Sustainable Enterprise Resource Planning system (S-ERP) [10,12]. SAP, Oracle, and Microsoft focus their S-ERP development on large companies.

Motivated by the lack of an SBM which integrates the assessment of sustainability (SA) and processes carried out and supported by the ERP system in small and medium manufacturing enterprises, an SBM-ERP model was developed.

Our approach is dedicated to manufacturing enterprises of the SME sector; the new contribution of this approach is visible in:

- Criteria for Sustainable Manufacturing (CS) were defined adequately to the specifics of the manufacturing enterprise of the SME sector.
- Sustainability Indicators (SI) were developed and selected for CS on the basis of results of the 'face-to-face' interviews with managers of Polish, metal industry manufacturing companies in western Poland (Europe) at the end of 2019.
- The Fuzzy Analytic Hierarchy Process (F-AHP) method was used for the final selection of SI because the Management Board of the examined company always assesses its validity. Selected SI were assigned their due status, based on their involvement in the three adopted areas Economic, Environmental and Social.
- The validity of SI was assessed using the F-AHP method, because it facilitates narrowing down and determining the

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order of the implementation of those actions needed for improving the sustainability level of the analysed company in relation to the specific business processes within the enterprise.

2. RESEARCH METHODOLOGY

The research was carried out in three stages: (1) analysis of the literature in order to define the research model, (2) the methodology to build the sustainable business model integrated with the ERP system (SBM-ERP), and (3) a case study.

2.1. Research model [13]

The SBM-ERP (Fig. 1) includes elements of the business model in line with the approach of Osterwalder and Pigneur [13], based on our work [14], namely: KP: key partners, KA: key activities, KR: key resources, VP: value proposition, CS: customer segments, CH: channels, CR: customer relations, CST: cost structure and RS: revenue streams.

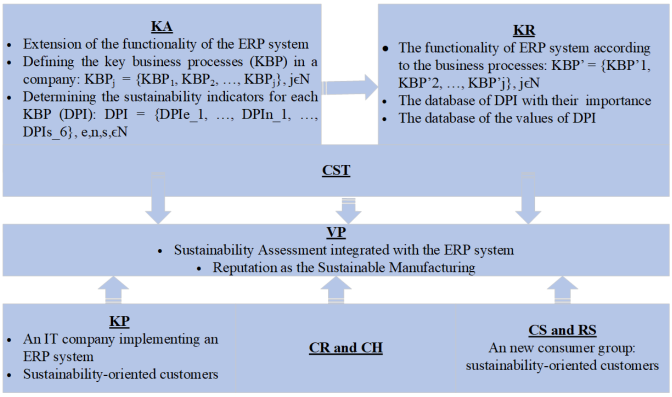

Fig. 1. Overview of an SBM integrated with ERP (SBM-ERP) [14]

The elements involved in our approach (Fig. 1) were based also on the results of empirical research from the implementation of the ERP system in a manufacturing company. The key activities (KA) include the defined need to extend the functionality of the ERP system by a module supporting the assessment of sustainability, as well as the need to define business processes in the enterprise under which the assessment of sustainability will be conducted and the appropriate Indicators for Sustainable Manufacturing will be assigned. Key resources (KR) are then needed, in order to conduct a sustainability assessment. Costs (CST) are related to the design and implementation of the new functionality of the ERP system supporting the sustainability assessment. Thanks to the implementation in the company of the first stage of the model, it is possible to expand the number of clients by a group of sustainability-oriented clients (CS, RS, CH, CR). The key partner (KP) is the company implementing new functionalities of the ERP system, which, at the same time, provides technical support for the continuous development of the system. New clients, namely sustainability-oriented clients also belong to this group (KP). Finally, the sustainability level of the manufacturing company, based on the Sustainability Indicators (SI) values of the analysed company can be obtained. Recommendations for improving the sustainability level in the analysed company are possible based on a comparison of the key SI values obtained with the reference values for the SI. In order to determine the reference SI values for a given class of enterprises, in a given area, the statistical data on a given country, which, in turn, should be averaged out for a given industry of enterprises, should be adopted (VP).

2.2. Methodology and methods

Each element of the proposed new business model was strictly described and formalised so that it can be useful to those external/internal teams implementing it.

KA1: Extension of the functionality of the ERP system

In the KA1 of SBM-ERP, the extension of the modules of the ERP system by a module supporting the assessment of sustainability is expected.

KA2: Defining Key Business Processes (KBP)

The defined need of extending the functionality of the ERP system by a module supporting the assessment of sustainability requires business processes to be defined in an enterprise, under which the assessment of sustainability will be conducted. KBP is a general analysis of processes in the company, thanks to which it is possible to identify areas and resources of the company, which must be determined for designing and implementing a new ERP module, supporting the assessment of sustainability.

The key processes (KA2) in a company supported by the ERP system, the realisation of which, influences sustainability levels in a manufacturing enterprise, are defined below: KBP = {KBP1, KBP2, …, KBP10}, $j \in N$, where: KBP1 – Production technology management; KBP2 – Production; KBP3 – Warehouse management; KBP4 – Sales; KBP5 – Supplier management; KBP6 – Logistics; KBP7 – Product design; KBP8 – Human resources management; KBP9 – Customer relationship management; KBP10 – Finance and accounting.

KA3: Determining the Sustainability Indicators (SI) for each key business process: DPI

Next, based on [9, 14–17] the sustainability indicators for Sustainable Manufacturing (SM) were defined (Table 1). Indicators for Sustainable Manufacturing (DPI) were defined adequately to the specifics of the manufacturing enterprise of the SME sector. The novelty of our approach (Table 1) is the development and assignment of sustainability indicators (SI) to the key business processes. This was established on the basis of the results of empirical research from Polish metal industry manufacturing companies in western Poland (Europe) at the end of 2019. Moreover, the following indicators have only recently been developed; a reduction in production costs and in logistics costs and in relation to the improvement in employee satisfaction: the number of complaints from clients. The new indicator was added, because the managers of the manufacturing companies

Table 1
DPI in each process

Sustainability dimensions	Business Processes within a company	DPI based on [9, 14–17]
Economic: DP_e, $e \in N$	KBP_1, KBP_2	DPI_{e_1} – production costs (monthly) $DPIe_1 = Cm + Cp_e + Ci + Ct; p\_eit \in N$ where: Cm – daily costs of materials used Cp_e – daily costs of production employees Ci – daily costs related to the use of machines Ct – daily costs related to the use of tools and equipment
	KBP_6	DPI_{e_2} – logistics costs (monthly) $DPI_{e\_2} = C_{i\_l} + C_{e\_l}; i\_l, e\_l \in N$ where: C_{i_l} – daily costs of internal logistics C_{e_l} – daily costs of external logistics
	KBP_2, KBP_{10}	DPI_{e_3} – total productivity (monthly) $DPI_{e\_3} = RTP/TR$ where: RTP – the ratio of the total production volume (monthly) TR – total number of resources used in production (monthly)
	KBP_{10}	DPI_{e_4} – ROA – return on assets
	KBP_{10}	DPI_{e_5} – ROE return on equity
	KBP_3	DPI_{e_6} – daily number of deliveries delayed (monthly)
	KBP_{10}	DPI_{e_7} – Profit Value (monthly)
	KBP_{10}	DPI_{e_8} – ROI – return on investment
	KBP_4, KBP_{10}	DPI_{e_9} – ROS – return on sales
	KBP_4, KBP_7	DPI_{e_10} – number of new products (annually, monthly)
Environmental DP_n, $n \in N$	KBP_1, KBP_2, KBP_3, KBP_4, KBP_5, KBP_6, KBP_7, KBP_8, KBP_9, KBP_{10}	DPI_{n_1} – water usage (monthly)
	KBP_1, KBP_2, KBP_3, KBP_4, KBP_5, KBP_6, KBP_7, KBP_8, KBP_9, KBP_{10}	DPI_{n_2} – energy usage (monthly)
	KBP_1, KBP_2, KBP_3, KBP_4, KBP_5, KBP_6, KBP_7, KBP_8, KBP_9, KBP_{10}	DPI_{n_3} – greenhouse gas emission (monthly)
	KBP_1, KBP_2, KBP_3, KBP_4, KBP_5, KBP_6, KBP_7, KBP_8, KBP_9, KBP_{10}	DPI_{n_4} – the number of environmental accidents (monthly)
	KBP_1, KBP_7	DPI_{n_5} – analysis of the toxicity of the materials used (monthly)
Social DP_s, $s \in N$	KBP_8	DPI_{s_1} – the amount of training *vis-à-vis* the awareness of sustainability, (monthly)
	KBP_5	DPI_{s_2} – average days payable (monthly)
	KBP_8	DPI_{s_3} – the amount of dedicated training (monthly)
	KBP_8	DPI_{s_4} – the number of programmes related to health care for employees (monthly)
	KBP_8	DPI_{s_5} – the number of programmes related to health insurance for employees (monthly)
	KBP_9	DPI_{s_6} – the number of complaints from clients (monthly)

stated that if customers are satisfied with the quality of products, this translates into employee satisfaction with a job "well done". Finally, the DPI indicators within each process for three dimensions of sustainability, namely: economic, environmental and social were determined (Table 1).

KR1: Functionality of the ERP System According to the Business Processes (KBP)

In this element of our SBM-ERP (KR1) the functionality of the ERP system, according to the tasks provided within business processes (KA1), should be defined first.

KR2: Database of DPI with their importance

To receive the database of the sustainability indicators with their importance, the Fuzzy Analytic Hierarchy Process (F-AHP) method is used. In our previous work [17], the literature analysis on the application of MCDA (multicriteria decision analysis) methods in the area of sustainable development assessment was conducted. In this article, the F-AHP method was chosen, because it allows for the inclusion of aspects in solving decision-making problems such as the assessment of the experience and reliability of decision-makers, uncertainty and also dependence between criteria. Using F-AHP, it is possible to determine the relative predominance of a particular SI from the immeasurable criteria of the framework of Sustainable Manufacturing; furthermore, it is possible to evaluate these criteria [18]. The F-AHP method was used for the final selection of SI because the Management Board of the examined company always assesses their validity. Selected SI was their due status, based on their involvement in the three adopted areas: Economic, Environmental and Social.

F-AHP is a method of assigning triangular fuzzy numbers to the criteria [19–22]. Definition of the fuzzy triangular method of hierarchical problem analysis [22]:

Triangular fuzzy number: the fuzzy number M ($R = (-\infty, +\infty)$) assigned to a function $\mu\_M(x) : R \to [0,1]$ must be:

$$\mu\_M(x) = \{ -(x/(m-l) - l/(m-l), \quad x \in [l,m] @ x/(m-u) - u/(m-u), \quad x \in [m,u] @ 0, \text{ otherwise}) \}, \tag{1}$$

where: $l \le m \le u$; m – modal value.

The fuzzy triangular number is referred to as (l,m,u). The operations on fuzzy triangular numbers are defined as follows: (2), (3) and (4):

$$\tilde{a}\_ij\hat{}(-1) = 1/\tilde{a}\_ij\hat{} = 1/(l,m,u) \simeq\sim (1/u, 1/m, 1/l), \tag{2}$$

$$\tilde{a}\_ij \oplus \tilde{a}\_ik = (l1, m1, u1) \oplus (l2, m2, u2) = (l1 + l2,\ m1 + m2,\ u1 + u2), \tag{3}$$

$$\tilde{a}\_ij \odot \tilde{a}\_ik = (l1, m1, u1) \odot (l2, m2, u2) \simeq (l1l2,\ m1m2,\ u1u2)\,. \tag{4}$$

The steps in the F-AHP method are as follows: (1) determining the hierarchical model: definition of the main criteria and detailed analyses, (2) assessment of the criteria according to pairwise comparison, using a point scale from Table 2, (3) setting preferences: creating a vector of criteria weights, (4) classification of decision variants. A scale vector (Table 2) is assigned to each selected α_i.

Thanks to the F-AHP method, each DPI indicator receives different parameter weights, which means that key areas of sustainability in an enterprise are determined for a given business process or a set of business processes, supported by the ERP system.

Table 2
Preference scale used in the F-AHP method

Relevance of criterion A compared to criterion B	Fuzzy number
equally important	(1, 1, 3)
moderately more important	(1, 3, 5)
much more important	(3, 5, 7)
of greater importance	(5, 7, 9)
the most important	(7, 9, 9)

KR3: Database of the values of DPI

The quantitative indicators (Table 1) for the KBP were established so that the data for calculating the values of these DPI could be received with the help of the ERP system. In our proposed model, the KBP is assigned to each DPI, supported by the ERP system. The new rules were developed in order to propose a new ERP module supporting the assessment of sustainability and presented in our previous work [9]. Generally in the economic dimension, the data for $\mathrm{DPI}_e = \{\mathrm{DPI}_{e\_1}, \ldots, \mathrm{DPI}_{e\_10}\}$ should be transferred from the actual ERP database to the new ERP module supporting the assessment of sustainability. In the environmental dimension, the routing of product and the bill of material for each product should be adopted from the ERP system to the new ERP module. The new data should include water consumption for each technological operation for semi-finished and finished products, power consumption for each technological operation for semi-finished and finished products, dioxide emission level for each material for semi-finished and finished products, data about accidents within each process, the toxic level for each material for semi-finished and finished products. In the social dimension, the values of $\mathrm{DPI}_s = \{\mathrm{DPIs}_{s\_1}, \ldots, \mathrm{DPI}_{s\_6}\}$ should be transferred from the actual ERP database to the new module.

We state that with the assistance of this module, the assessment of sustainability within a manufacturing company will be conducted. Hence, to receive the SI values of the sustainability of the dimensions, both economic and social, the data, currently available in the ERP, is linked to this new module. Secondly, the new base date and the new rules for receiving DPI values in the environmental dimension are created.

CST: Cost structure

This element of our model is an element which bonds key activities (KA) and key resources (KR) and depends on the expenditure necessary to carry out additional design and programming work in order to implement the indicators (Table 1) and rules indicated, by calculating these values. In addition, the "F-AHP analysis" module should be added to the ERP system to receive weighted values of individual indicators assigned to business processes (Table 2). CST is also dependent on the costs associated with the design of matching indicators and the business processes implemented in the company. These costs can be understood as external expenditures regarding the activities of external experts or may be incurred inside the company.

KP: Key partners

Next, the key partners (KP) are defined as the IT company implementing an ERP system (KP1) and sustainability-oriented customers (KP2). The choice of a company to integrate the proposed business model with the ERP system already implemented should be based on the experience gained when originally co-operating with the company which implemented the existing ERP system. Sustainability-oriented customers are also important partners in the proposed model. It is assumed that customers will receive information that the level of sustainable development is monitored for the business processes implemented in the enterprise and working in the business model.

CS and RS: Customer Segments and Revenue Streams

The next part of the model (CS and RS) is defined as an increase in revenues to the enterprise due to deepening and strengthening contact with existing and future sustainability-oriented clients.

CR and CH: Customer Relations and Channels

The element bonding KP with CS and RS are activities aimed at good relations with existing clients and the acquisition of new ones, thanks to the image which sustainability-oriented companies have built.

VP1: Value proposition: the assessment of sustainability integrated with the ERP system

The main element of the proposed SBM-ERP is VP. It is stated that the assessment of sustainability should be integrated with the ERP system so that the company's manager can monitor its SD level and conduct activities towards obtaining the status of Sustainable Manufacturing (SM, element in SBM-ERP:VP2).

In order to determine whether a given DPI value indicates a satisfactory level of SI, the values obtained should be referred to as the so-called reference values for a given class of enterprises in a given area. Usually, these are values obtained from statistical data on a given country, which should be averaged out for a given industry of enterprises. Next, each DPI value will be compared with the reference value of the DPI for a given class of manufacturing enterprises. The key business process marked in red will be strongly recommended for improvement. The KBP marked in yellow will be recommended for improvement and the one marked in green will be recommended to be maintained.

One example of determining the DPI level is shown in the next chapter, using as an example a medium-sized, Polish metal manufacturing enterprise.

VP2: Value proposition: sustainable manufacturing

If the analysed manufacturing company obtained in all areas of sustainability dimensions, the economic, environmental and social dimensions, then the satisfactory DPI level, namely, the DPI criteria values, are the level recommended to be maintained and the enterprise obtains the status of "Sustainable Manufacturer".

2.3. A case study

The study was carried out based on a real case study of a medium-sized, Polish metal manufacturing enterprise. This company makes steel structures for the construction industry along engineered-to-order lines. The products are made on the basis of trusted, technical documentation and delivered directly to the construction site. Presenting this example is intended to solve the given research of searching for a business model, integrating the Assessment of Sustainability (SA) and the processes carried out and supported by the ERP system within a company from the small and medium enterprises sector (SMEs).

3. RESEARCH RESULTS

The proposed SBM-ERP model was verified in real Polish manufacturing in the SME sector, producing steel structure elements, based on the data and information received from the Management Board and from the database of the ERP system.

KA1: The company has attained the second level of maturity because, generally, information technologies are implemented and used. The company has and uses an ERP system that supports the following processes: KBP1: Production and Technology Management, KBP2: Production, KBP4: Sales and KBP6: Logistics. Nowadays, sustainable production and the implementation of Industry 4.0 technology require the design and implementation of new functionality in an ERP system used in a provided case study regarding the assessment of the level of sustainable development.

KA2: The processes supported by the ERP system in the enterprise considered were defined. A detailed description can be found in [14].

KA3: Next, as proposed in our approach, the sustainability indicators in each process were determined (Table 3).

Table 3
Sustainability indicators within each process in the analysed company

Sustainability dimensions	Processes	DPI
Economic: DP_e, $e \in N$	KBP_1, KBP_2	DPI_{e_1}
	KBP_6	DPI_{e_2}
	KBP_2	DPI_{e_3}
	KBP_4	DPIe_9
	KBP_4	$DPI_{e\_1}0$
Environmental DP_n, $n \in N$	KBP_1, KBP_2, KBP_4, KBP_6	DPI_{n_1}
	KBP_1, KBP_2, KBP_4, KBP_6	DPI_{n_2}
	KBP_1, KBP_2, KBP_4, KBP_6	DPI_{n_3}
	KBP_1, KBP_2, KBP_4, KBP_6	DPI_{n_4}
	KBP_1	DPI_{n_5}

Due to the fact that the obtained data and information from the ERP system concern only the aspects in the area of sustainable development in economic and environmental dimensions, the social dimension is not analyzed in further stages of the SBM-ERP model verification.

KR1: The functionality of the ERP System, according to the Business Processes (KBP) analysed and supported by the ERP system was defined. The ERP system module that supports KBP1 includes the following tasks: the technical specification of products, the integration of products with CAD documentation, the definition of material indexes, the development of the specifications bills of materials, the specification of technological resources, the development of technology specifications, specification of co-operation processes and calculation of own costs and of products. KBP2: management of production orders, production planning and scheduling, balancing the material requirements (MRP), balancing the production capacity (MRP II), registration of manufacturing operations, supervision of production costs, production control, for example: changing production routings, changing manufacturing resources. KBP4: enquiry registration, quotation preparation – carried out automatically, based on enquiries, verifying sales conditions, based on defined rules, such as delivery date, prices, discounts, payment method, etc., registration of orders – carried out automatically, based on the quotation automatically confirmed by the customer via email or EDI, supervision of the completion of orders, registration of invoices, carried out automatically, based on the orders, confirmation of payment by the customer, warranty and post-warranty service. KBP6: verification of the date and volume of the delivery of the material (MRP), materials and services purchasing, physical inventory management (identification of material flow, barcodes), inventory valuation, the internal and external transportation of orders, the turnover of materials, semi-finished products and ready products, receipts for materials and the issue of materials.

KR2: The F-AHP method was applied to determine the importance of the criteria describing the SM level. Using linguistic variables, the rules for DPI_{e_1}, DPI_{e_2}, DPI_{e_3} (U), DPI_{n_2} (D), DPI_{n_3} (I) are defined (Table 4). Based on the subjective assessment of the manufacturing manager and applying the F-AHP method, the importance of the criteria: $wDPI_{e\_1}$, $wDPI_{e\_2}$ $wDPI_{e\_3}$, $wDPI_{n\_2}$, $wDPI_{n\_3}$ and the weight values after standardisation: $swDPI_{e\_1}$, $swDPI_{e\_2}$, $swDPI_{e\_3}$, $swDPI_{n\_2}$, $swDPI_{n\_3}$ (Table 5) was determined.

Table 4

The importance of SI

$wDPI_{e\_1}$	$wDPI_{e\_2}$	$wDPI_{e\_3}$	$wDPI_{n\_2}$	$wDPI_{n\_3}$
0.4146	0.4853	0.0717	0.1092	0.1282
$swDPI_{e\_1}$	$swDPI_{e\_2}$	$swDPI_{e\_3}$	$swDPI_{n\_2}$	$swDPI_{n\_3}$
0.3429	0.4014	0.0593	0.0903	0.1060

Based on the analysis results, in analysed manufacturing, the most significant SI are: DPI_{e_2} (logistic costs) and DPI_{e_1} (production costs).

KR3: The values of the quantitative indicators (Table 5) could be obtained with the help of the ERP system. The company's managers decided that the additional functionalities of the ERP system would include the following indicators: DPI_{e_1}, DPI_{e_2}, DPI_{e_3}, DPI_{n_2} and DPI_{n_3}. Therefore, the additional functionalities of ERP have been added. The rules for the additional functionality of the ERP are detailed and defined:.

Table 5

The significance of each SI in the case study

Sustainability	Processes	SI	SI value	The significance of each SI
Economic: DP_e, $e \in N$	KBP_1 KBP_2	DPI_{e_1}	–	2
	KBP_6	DPI_{e_2}	–	1
	KBP_2	DPI_{e_3}	72.3	5
Environmental: DP_n, $n \in N$	KBP_1 KBP_2 KBP_4 KBP_6	DPI_{n_2}	48020 kWh	4
	KBP_1, KBP_2, KBP_4, KBP_6	DPI_{n_3}	354.2 kg	3

• for DPI_{e_1} – production costs

The daily production volume is about 70 steel structures. Based on the bill for the materials and routing in the ERP system, the self-cost calculation can be prepared (Table 6). The calculation of self-costs enables the price of the finished product to be proposed while analysis of the requirements of the routing and resources enables the delivery date of the product to be determined.

Table 6

Production costs

Cost category	Value [EUR]
Daily cost of materials	18 085
Daily cost of production employees	13 552
Daily cost related to the use of machines	870
Daily cost related to the use of tools and equipment	170
Daily self-cost	33 477
Overheads (25%)	8 369
Total daily cost for product	41 046
Total monthly production cost – DPI_{e_1}	820 920 euro

Using the data, a quotation is prepared in the ERP system and sent to the customer. The daily costs related to the use of machines are calculated and are based on amortisation data from the ERP system while the cost of the tools and equipment are based on the average daily utilisation of such resources, as registered in ERP.

• for DPI_{e_2} – logistic costs

The costs of logistic workers are obtained from the human resources management module of the ERP; the daily costs of forklifts are obtained from registration to operational logistics, in the production module; warehouse costs are obtained from the module of material management and the costs of logistics equipment and external transport are obtained from the financial accounting module (Table 7).

Table 7
Logistics costs

Cost category	Value [EUR]
Average daily cost of logistics workers (4 workers)	325
Average daily cost of forklifts	180
Average daily cost of warehouses	85
Average daily cost of logistics equipment (amortisation)	52
Average daily cost of external transport	220
Total daily cost	862
Total monthly cost – DPI_{e_2}	17 240

• for DPI_{e_3} – productivity (Table 8)

Table 8. includes the information on production and productivity over the next 4 months.

Table 8
Productivity

	Sep '19	Oct '19	Nov '19	Dec '19
Production volume [pieces]	1597	1680	1550	1227
Production volume [EUR]	1 421 330	1 545 600	1 413 600	1 105 527
Number of registered hours (all machines)	1724	1962	1686	1514
Cost of machines [EUR]	19 140	20 880	18 270	17 400
Productivity (volume pieces/time)	0.9	0.9	0.9	0.8
Productivity (volume EUR/costs EUR)	74.3	74.0	77.4	63.5
Moving average productivity (volume EUR/costs EUR for 4 month) DPI_{e_3}				72.3

• for DPI_{n_2} – energy usage

The detailed routing included in the ERP system was presented in [9]. We know that total power consumption for the finished product is 34.3 [KWh] for the following operations: assembly, quality control and packing, for semi-finished product, for the operations: cutting, drilling, milling, welding, grinding, powder coating is 11.5 [KWh], for the second semi-finished product, for the operations: cutting, milling, welding, grinding is 16.6 [KWh], and for the third second semi-finished product, for the operations: cutting, drilling and welding is 6 [KWh]. To obtain the monthly, energy usage indicator, multiply the value: total power consumption by the daily number of products produced then multiply by 12 months.

• for DPI_{n_3} – greenhouse gas emission (monthly)

The technical documentation for steel structures is delivered in electronic form. In the first step, the analysis of the documentation is carried out for technological feasibility. If the order can be completed, the bill, both for the material and the routing of the finished product is prepared. Based on the detailed bill for the material in the ERP system [9], the KG of CO_2/unit is calculated as 2.53 for the finished product. To obtain the monthly CO_2 emission indicator, multiply the value: KG of CO_2/Unit by the daily number of products produced and then multiply by 12 months.

Next, the following values of SI were received:

- for DPI_{e_1} – total monthly production costs: 820 ∼ 920 euro,
- for DPI_{e_2} – total monthly logistic costs: 17 ∼ 240 euro,
- for DPI_{e_3} – average value of productivity based on the data from four months: 72.3,
- for DPI_{n_2} – energy usage: 48 020 KWh per month,
- for DPI_{n_3} – greenhouse gas emission (monthly): 354.2 kg.

In order to increase the level of sustainable development of company and obtain SM status, firstly, corrective actions should be taken in the areas of production and logistics. To monitor the effects of introduced changes implementation of the prosed SBM-ERP model requires additional functionalities to be designed for the ERP system, e.g., implementation of the rules needed for receiving DPI values, F-AHP method and finally the proposed assessment of sustainability. The proposed additional functionalities of the ERP system allow for continuous monitoring of the SD level in the enterprise, which enables the analyzed enterprise to be SM and thus acquire new customers (part KP of the SBM-ERP model). Moreover, it is expected that the integration of the proposed model with the ERP system will allow us to increase RS and naturally CS. In our further works, such indicators will be built that will allow for monitoring the changes in the level of these two elements of the SBM-ERP model: CS and RS.

In our case study, the VP1 (Table 9) was created and integrated within an ERP [14]. In order to receive the reference values for the DPI indicators the data from the Polish Central Statistical Office in Poland (Statistical Yearbook of Industry – Poland, 2021) was adopted. We calculated the IS values according to this assumption: 32% of manufacturing companies in Poland are in western Poland (place of activity of analysed manufacturing):

- for DPI_{e_1} – annual production costs per enterprise: 0.1065 million EUR,
- for DPI_{e_2} – no data available,
- for DPI_{n_2} – energy usage (monthly) per company: 0.0032 GWh,
- for DPI_{n_3} – CO_2 emission (monthly) per company 0.0001 thousand tonnes.

Table 9
Assessment of sustainability integrated with the ERP system

The importance of DPI in Sustainable Manufacturing	Processes	The value of DPI in Manufacturing according to their importance	The reference value of criteria in Sustainable Manufacturing	SI assessment
1	KBP_1, KBP_2	$vDPI_{e\_2} = 346.05$ euro/month	–	(green)
2	KBP_6	$vDPI_{e\_1}$=0.01407 mln euro/month	0.1065 mln euro/month	(green)
3	KBP_2	$vDPI_{n\_3}$=0.0035 thousand tonnes	0.0001 thousand tonnes	(red)
4	KBP_1, KBP_2, KBP_4, KBP_6	$vDPI_{n\_2}$=0.0048 GWh	0.0032 GWh	(yellow)
5	KBP_1, KBP_2, KBP_4, KBP_6	$vDPI_{e\_3}$=72.3	100	(yellow)

For a manufacturing company to receive the status of Sustainable Manufacturer (VP2), activities that reduce CO_2 emissions and energy usage must be implemented. The proposed SBM-ERP model facilitates ongoing monitoring of defined indicators and also allows for changes resulting from the implementation of corrective actions to be monitored. Managers should now immediately improve the value of the SI indicated (especially marked in red in Table 9).

4. DISCUSSION

As a result of the application of the proposed SBM-ERP approach, the assessment of the level of sustainable development was obtained in the form of new functionality, added to the ERP system. The values of the sustainable development indicators assigned to the following processes were obtained: KBP1: Production and Technology Management, KBP2: Production, KBP4: Sales, KBP6: Logistics. Next, these SI values were compared with reference values received from the Polish Central Statistical Office in Poland. The assessment of the sustainability table integrated with the ERP system (Table 9) then identifies areas that require corrective action, marked in red.

For the SI namely $vDPI_{e\_1}$ (*production cost*) and $vDPI_{e\_2}$ (*logistics cost*), no action needs to be taken for the improvement of the sustainable level of the analysed manufacturing, Table 9 marked in green.

For the SI namely $vDPI_{e\_3}$ (*productivity*) and $vDPI_{n\_2}$ (*energy usage*) action should be taken in order to have a higher level of sustainable development in the analysed manufacturing, Table 9 marked in yellow.

For the DPI indicator: $vDPI_{n\_3}$ (*greenhouse gas emissions*) further actions for improving the sustainable level of the company analysed are required, Table 9 marked in red.

The most important technological processes completed in the selected production company are the plasma cutting of steel plates and the welding of structural elements. Both processes are energy-intensive and result in high CO_2 emissions. In order to improve the indicators of sustainable development, the following corrective activities have been proposed:

- Introduction of new procedures for preparing material for welding in order to reduce errors, eliminate gaps, corrections and re-working,
- Optimal selection of plasma cutting and welding parameters (voltage, current, shielding gases, etc.) in order to shorten operating times, eliminate production shortages and reduce energy consumption, e.g., by using appropriate algorithms to optimise the cycle time.
- Changes in the volume and frequency of deliveries of batches of materials, in order to reduce the CO_2, generated by internal and external transport.

Our proposed SBM-ERP model makes it possible to identify areas of sustainable development in which it is essential to take corrective actions within manufacturing. Unfortunately, one limiting factor of the approach is the inability to automatically generate possible scenarios of the actions needed. The proposed activities are currently indicated by the company's Management Board. However, the new contribution of our SBM-ERP model is observed in the automatic acquisition of data from the ERP system to determine the level of sustainable development, thanks to the development of new functionality of the ERP system (KA and KR in the SBM – ERP), the use of which enables real-time monitoring of the level of production sustainability (VP in the SBM-ERP).

5. CONCLUDING REMARKS

ERP systems have been implemented for over 25 years in different industries and nowadays perform the key function for the introduction of Industry 4.0 technologies. So far, their main task has been to support decisions in the field of improving the efficiency of business, production and logistics processes. The concept of sustainable development of enterprises requires the role and functionality of ERP systems to be redefined. The concept of the SBM-ERP system proposed in this article facilitates the use of standard ERP systems to support the sustainable development of enterprises. So, our model can be integrated with any ERP system. The used ERP system within manufacturing can be expanded by the proposed module supporting the assessment of sustainability. This requires the monitoring of additional data in the ERP system (e.g. energy consumption of technological operations, CO_2 emissions, etc.), defining criteria for evaluating the level of sustainable development, implementing analytical tools based on the F-AHP method and continuous monitoring of changes in the adopted reference values for a given industry of enterprises. It should be emphasized that the proposed approach has little impact on the total cost of ownership of the ERP system. The case study presented in the article shows the practical usefulness of the proposed approach in the example of a medium-sized manufacturing company in the metal industry.

The presented, innovative approach to integrating the SBM-ERP sustainability assessment in small and medium-sized manufacturing enterprises facilitates not only the monitoring of selected indicators for the purpose of evaluating the level of sustainable development but also developing a strategy for improving enterprise assessment indicators. The SBM-ERP developed can be treated as a pattern for conducting continuous assessment and monitoring of the manufacturing sustainable development level. Access to objectively defined criteria for assessing the sustainable development of enterprises for a given industry (for example by the EU commission) is important for the proper functioning of the proposed approach. Another challenge for the implementation of SBM-ERP in SMEs is the reduction of costs related to data acquisition by automatic data acquisition directly from production processes (for example reading data on the energy consumption of operations directly from machines).

In our further work, we plan to build an information system that will be an implementation of our SBM-ERP model. Then this developed system can be considered as the separate system independently of the ERP system used in manufacturing, but with the possibility of integration with any ERP system. In addition, a methodology for the implementation of the SBM-ERP system to the industrial practice of enterprises for the selected industry will be developed. Moreover, as part of further research, decision algorithms for ERP systems will be developed in the selection of partners, technologies and materials ensuring sustainable development of enterprises.

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