Sustainability Classification for SMEs from the Remanufacturing Sector

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ABSTRACT

The objective of this study is to determine the method for the sustainability classification of Small and Medium Sized Enterprises from the remanufacturing sector. The literature lacks a simple method for assessing sustainability dedicated to SMEs in the remanufacturing sector. The aim of this paper is to present a new, effective, and objective method for assessing sustainability with the use of criteria of sustainability. Designed by the authors, the Sustainability Assessment Method (SAM) uses an averaged traits quality approach. The method aims to assess the current situation in a company regarding the sustainability level of operations, helps to identify the weaknesses in current operations, and then prioritizes improvements that need to be taken. The designed method gives a possibility of ranking companies and supports decision makers to take action in order to achieve a better sustainability class. The paper also presents a numerical example to show how the method can be applied in an actual company.

Keywords: Sustainability classification, SME, Sustainable, Averaged traits quality method

INTRODUCTION

The concept of sustainable development (hereafter: SD) has been a significant focal point for decision makers in businesses (Singh et al., 2009). With the increasing importance of sustainability, companies aim to apply sustainability policy.

At a company level, the requirements of sustainability policy can be considered as (Golinska and Kuebler, 2014):

- economical utilization of the resources,
- environmentally friendly utilization of the resources, and
- utilization of the resources that provides ergonomics and safety at the facility and minimizes the negative impact on the surrounding communities.

The need for assessment was recognized more than forty years ago. Since then, many assessment methods have appeared in the literature. Singh et al. (2009) prepared a detailed presentation of sustainability assessment methodologies.

It was assumed that if a company were more sustainable, it would achieve better results. Consequently, there is a strong desire to comprehensively assess sustainability levels.

Sustainability assessment required answering the following questions:

What is the object of the assessment? – Determining what will be measured and considering the characteristic of the analyzed object (e.g., size of the company, sector, etc.).

How to measure sustainability? – This question is about the specific sustainability indicators system (SIS) used to determine the level of sustainability. Measurements can range from objective and quantitative to more subjective or qualitative metrics. In order to better identify the current situation in a company and to find the optimization potential, a system of performance measures is required to help managers follow up, coordinate, control, and improve different aspects of organizational activities (Kollberg et al., 2005).

How use the results of the assessment? – This question is about the future of the object after the assessment. Should some actions be taken? How should the actions/changes be prioritized to best improve the level of sustainability?

The literature includes many examples of indexes and methods for evaluating the performance of sustainable development (Böhringer and Jochem, 2007; Singh et al., 2009; Li et al., 2009; Rinne et al., 2013). Böhringer and Jochem (2007) and Pintér et al. (2012) reviewed the consistency and meaningfulness of various indicators and proposed many principles and theoretical frameworks for assessing sustainable development. Despite the fact that many possibilities of expressing sustainability index systems (SIS) exist, relating them to SMEs is problematic because of three issues:

Issue 1 – Sustainability indexes refer to global issues

The following example indicators related to global issues can be distinguished:

- human Development Index (UNDP, 2005) – focuses on human development (duration of healthy life, being knowledgeable, and standard of living);
- ecological Footprint (Wackernagel and Rees, 1997) – focuses on people's influence on the environment;
- environmental Performance Index (Esty et al., 2006) – focuses on protection of human health from environmental harm and protection of ecosystems.

Issue 2 – Sustainability indexes are dedicated for each pillar of sustainability separately

Appropriate sustainability assessment for SMEs with the use of aggregated indexes is unavailable. Except for the lack of aggregated sustainability indicators, the following indexes dedicated for each pillar of sustainability are available:

- environment – e.g., energy consumption, water consumption, waste generation, GHG emissions, etc.

- economic (cost perspective), with the most popular method quoted in the literature of assessing the economic aspects of sustainable development – Life Cycle Cost (LCC).
- social – includes health and safety, human rights, employment, living conditions, crime, corruption, etc. (Schau et al., 2011; Fatimah, 2013).

Issue 3 – Limited resources of SMEs

Most of the companies in UE are SMEs. Human and financial resources capable of implementing complex performance measurements systems are limited. Remanufacturing companies are specific kind of business. It is crucial to ensure an effective decision support model for a goal-oriented analysis and implementation of appropriate measures for increasing sustainability in remanufacturing SMEs. In most cases, SISs dedicated to SMEs are lacking.

Universal and simple procedures adequate for SMEs, which need some guidelines for decision-making in the context of more sustainable resource utilization, are lacking. In order to better identify the current situation and to find the potential for improvement, we designed the Sustainability Assessment Method (hereafter: SAM) to help managers in decision-making by facilitating the control and improvement of different aspects of the business operations from a sustainability perspective.

The major purpose of this research is to develop the SAM for assessing sustainability in remanufacturing SMEs. The method was verified on a group of remanufacturing companies.

SAM, a new method, uses an Averaging Quality Rating method. The originality of the procedure relies on the use of an Averaging Quality Rating method; this is used for indicators analysis in order to make them comparable, despite different measurement methods (qualitative or quantitative).

MATERIALS AND METHODS

In this research, we designed a new method to determine the sustainability class of SMEs from the remanufacturing sector. This method assesses the current situation in a company regarding the sustainability level of operations, helps to identify the weaknesses in current operations, and then prioritizes improvements that need to be taken. The method has five steps (Figure 1).

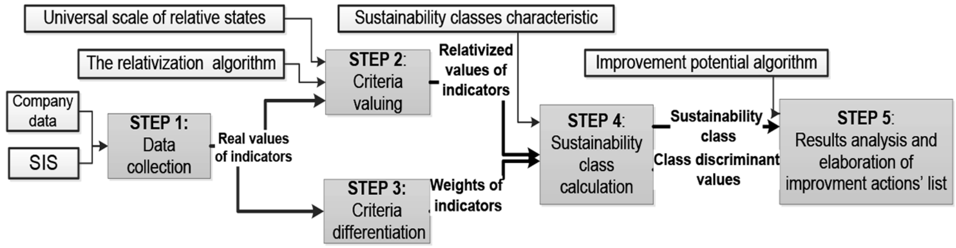

Figure 1. Stages in the sustainability assessment method.

In the first step, data from the company are collected to calculate the real values of sustainability indicators. In the second and third steps, carried out simultaneously, criteria are valued and differentiated. In the fourth step, the sustainability class is calculated. A final assessment of the sustainability class information as well as the class discriminant is conducted using an appropriate algorithm. Finally, lists of improvement actions are developed.

The bases for the method elaboration are: literature analysis, preference analysis for the third Thurstone's quarter, survey, and Averaging Quality Rating method. The major purpose of the method is to determine the sustainability class. The following assumptions were made:

a) dedicated for remanufacturing company system of sustainability indicators (SIS);
b) each indicator has an independent level of importance; and
c) relationships between indicators are not analyzed.

Sustainability Assessment Method (SAM) classifies a company into one of three assumed classes of sustainability (Figure 2).

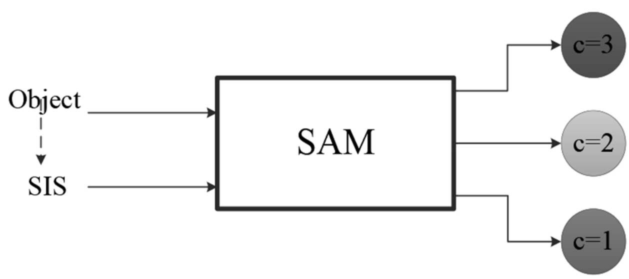

Figure 2. Sustainability assessment method context diagram (own elaboration based on Kosacka et al., 2015).

Sustainability Assessment Method (SAM) works as a black box transforming input into output. The input includes an object and Sustainability Indexes System (hereafter: SIS) and the output is the sustainability class of the company. The sustainability class (c) can be defined at various levels of detail (company, sustainability pillar, or indicator). The analyzed company is an object. It has its own characteristics (determined by size of the company, product range, etc.) that affects SIS.

Sustainability indicators system

The method used the sustainability indicators system dedicated for remanufacturing companies elaborated by Golinska et al. (2014) (Table 1).

Table 1. Sustainability indicators for remanufacturing companies (Golinska et al., 2014).

No	Indicator	Description
Economic performance		
1	OEE	Overall equipment effectiveness
2	RPF	Remanufacturing process flow
3	Planning adequacy	Adequacy of remanufacturing process planning
4	AMT	Availability of machines and tools
5	Level of executed orders	
6	OOS	Availability of materials (overall out of stock)
Environmental performance		
7	Energy consumption level (ECL)	Energy consumption per one core
8	Waste generation level (WGL)	Amount of waste generated
9	MRR	Material recovery rate
10	Generated emissions level (GEL)	Amount of emissions (CO_2, water, sewage) per one regenerated core (product)
Social performance		
11	Employment	Change in the level of employment in the period
12	Staff training	Percentage of employees who participated in additional training
13	Harmfulness of the remanufacturing process (HRPP)	Refers to the consequences that are associated with threat to safety and health of workers in the remanufacturing process
14	Comfort level	Identification of wasted (muda) time of workers due to inefficient workplace design
15	Innovation level	The number of implemented innovations in the enterprise proposed by employees

Each indicator is a function of three variables:

$$i = f\,(m, r, v) \tag{1}$$

Where *m* determines type of the indicator from the measurability perspective (qualitative or quantitative); *r* etermines the range of values of the indicator (e.g., percent values from 0-100, number values, scale); and *v* determines the type of valuing function (maximum or minimum).

The first important feature of the indicator is the type of the indicator. There are two options: qualitative and quantitative, in terms of what is related to the value range of the indicator. The quantitative indexes include percent values (0 -100%) and number values (without limitations). The qualitative option uses scales (e.g., Likert scale).

Stages of the sustainability assessment method

Data collection. For the defined system of indicators (SIS) at the first stage of SAM, the data required to determine the real value of indicators should be collected. Then, the real value of each indicator should be calculated.

Criteria valuing. The value and unit of indicator represents the absolute state of physical quantity (real value of the indicator).

To consider the class of sustainability according to SIS, the criteria must be comparable; the quantization method (Driscoll et al., 2007) based on Averaging Quality Rating Method ensures this (described in detail by Kolman, 2013). Hence, in the method of valuation, a rule of relative states is considered. The criteria valuing stage relies on relativization, transforming the absolute state (real value of indicator) to a relative state (for measurable factors), or selecting the proper relative state (from the universal scale of relative states) - for qualitative indicators (Figure 3).

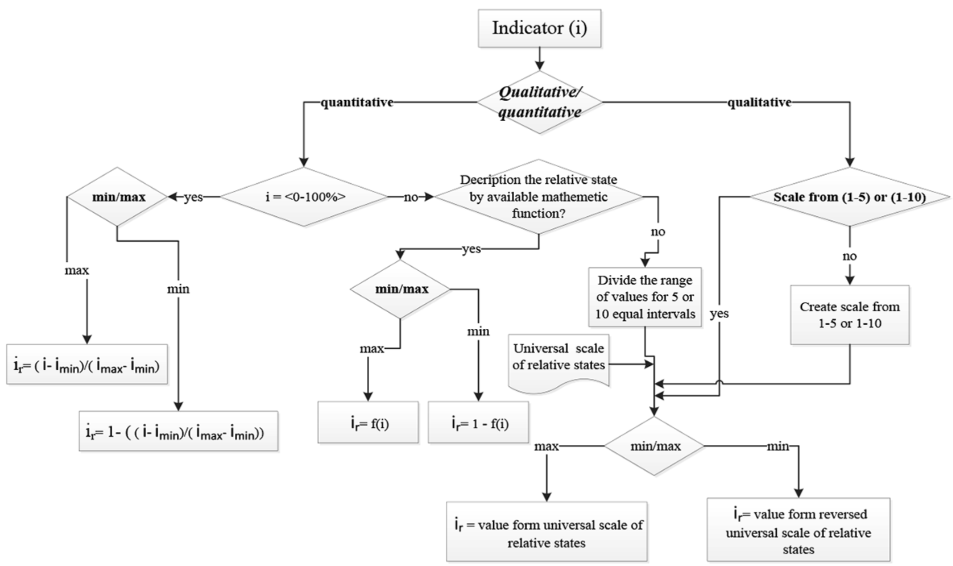

Figure 3. Relativization of the indicator algorithm (own elaboration based on Kosacka et al., 2015).

Each indicator is analyzed according to measurability, range of values, and type of valuing function. Quantitative indicators can be presented in percent or as a mathematic function; otherwise, the range of values can be represented as 5 or 10 equal intervals. For qualitative indicators, a scale can be created that later will be compare with the universal scale of the relative states (Figure 4).

The effect of relativization is determined as i_r - relative state of analyzed indicator, which will be used in further calculations. All of the analyzed criteria are expressed in unitless terms, in a range between 0 and 1 (Dudek-Burlikowska, 2006). Before relativization, comparing quantitative and qualitative indicators was impossible.

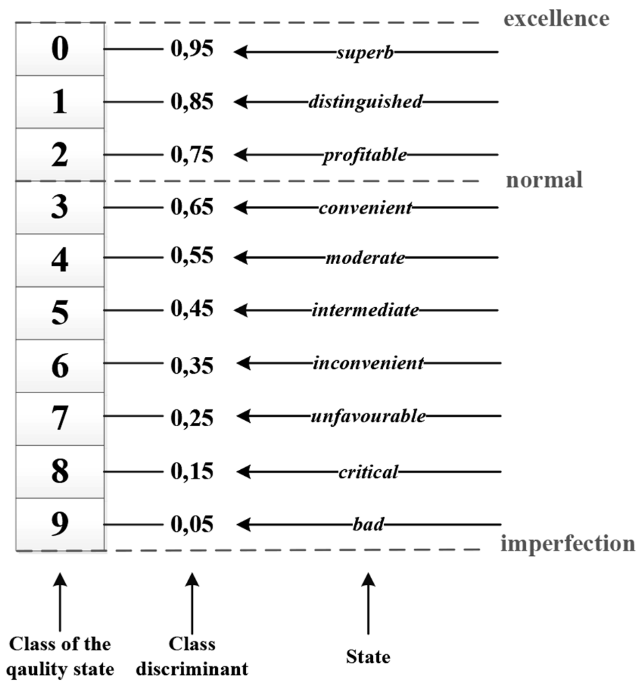

Figure 4. Universal scale of quality relative states (hereafter: usqrs) (adapted from Dudek-Burlikowska, 2006).

The universal scale of quality relative states becomes a sample for relative states interpretation. The 10 classes of quality states are described in words and by numbers. In its general meaning, quality class is a set of information about the qualitative properties of the analyzed object that facilitates the identification of the requirements and the achieved results. It was assumed that the class “0” corresponds to the highest level of quality and class and the class “9” corresponds to the lowest level of quality (Dudek-Burlikowska, 2006).

The *criteria valuing* stage had considerable impact on the SAM. In the result, comparability of different indicators was provided. Table 2 presents the calculation of the relative state of each indicator (i_r).

Table 2. Relativization for SIS.

Indicator	Indicator's characteristic: Type (Qualitative/ Quantitative)	Indicator's characteristic: Value range (i)	Indicator's characteristic: Target value (min/max)	I_r calculation	Eq.
OEE	Quantitative	0-100 [%]	Max	$i_r = \frac{i - i_{min}}{i_{max} - i_{min}}$	(2)
Planning adequacy					
Level of executed orders					
MRR					
Staff training					
Comfort level					
Innovation level					
WGL	Quantitative	0-100 [%]	min	$i_r = 1 - \frac{i - i_{min}}{i_{max} - i_{min}}$	(3)
ECL	Qualitative	Scale (1-5)	min	$i_r = \begin{cases} 1 \; for \; i = 1 \\ 0{,}8 \; for \; i = 2 \\ 0{,}6 \; for \; i = 3 \\ 0{,}4 \; for \; i = 4 \\ 0{,}2 \; for \; i = 5 \end{cases}$	(4)
GEL					
RPF	Qualitative	Scale (1-5)	max	$i_r = \begin{cases} 0{,}2 \; for \; i = 1 \\ 0{,}4 \; for \; i = 2 \\ 0{,}6 \; for \; i = 3 \\ 0{,}8 \; for \; i = 4 \\ 1 \; for \; i = 5 \end{cases}$	(5)
AMT					
OOS					
HRPP	Quantitative	R (divided into 5 intervals)	min	$i_r = \begin{cases} 1 \; for \; i \in < i_{min}, i_1) \\ 0{,}8 \; for \; i \in < i_1, i_2) \\ 0{,}6 \; for \; i \in < i_2, i_3) \\ 0{,}4 \; for \; i \in < i_3, i_4) \\ 0{,}2 \; for \; i \in < i_3, i_{max}) \end{cases}$	(6)
Employment	Quantitative	0-100 [%]	max	$i_r = \frac{i}{i + \frac{3}{7}}$	(7)

The major problem during this stage was to establish the mathematic function for the *Employment* indictor, which had values in the range of 0-100%. The second problem was related to the *HRPP* indicator, because the values were from a set of real numbers that were divided into 5 intervals. Table 1 is a result of applying the relativization algorithm and universal scale of relative states.

Criteria differentiation. It was assumed that particular indicators are not of the same importance in a case of a sustainability assessment. Each indicator is perceived from the perspective of its importance level η_i, where $0 < \eta_i \leq 1$. The closer the value of η_i to 1, the more important the criterion is. There are different possibilities of establishing weights of each indicator – e.g., the weighted average method, the third quarter preferential Thurstone's method (Thurstone, 1927), and the Analytic Hierarchy Process (AHP) (Saaty, 2008). In the presented method, the third quarter preferential Thurstone's method was used to determine the significance of each indicator. In order to establish the weight of all indicators, 15 experts from the production field were surveyed (Golinska et al., 2014)

Sustainability class calculation. The first step is to calculate the class discriminant (Eq. 8), which is a determinant of the sustainability class (Eq. 9).

$$x_i = \eta_i * i_r \tag{8}$$

Where x_i is a class discriminant of *i-th* indicator.

Taking into account the relative state of analyzed indicator (i_r) and its weight (η_i), the class discriminant is computed.

Sustainability class is a function of the class discriminant's value (Eq. 9):

$$c = f(x) \tag{9}$$

Where *c* is a sustainability class, c = <1,2,3>; *x* is a class discriminant, x ϵ (0,1)

Sustainability class depends on the value of the class discriminant (Eq.10)

$$c = \begin{cases} 1 \; for \; x \in (1;0{,}75> \\ 2 \; for \; x \in (0{,}75;0{,}45> \\ 3 \; for \; x \in (0{,}45{,}0) \end{cases} \tag{10}$$

It was assumed that three classes of sustainability would be determined according to the scale in Table 3. Limits of the intervals were arbitrarily defined.

Table 3. Sustainability classes characteristic (Golinska et al., 2014).

Class	Interval	General assessment	Remarks
c = 1	(1-0,75>	Favorable	Good situation, monitoring required
c = 2	(0,75-0,45>	Normal	Required corrective actions as soon as it is economically and organizationally possible
c = 3	(0,45;0)	Negative	Required immediate corrective actions

Intervals were determined arbitrarily by the authors of this paper based on a Universal scale of universal relative states, taking into account the semantic definitions of the state term.

The scope of this paper is to determine the sustainability level of the company. According to Eq.8, the class of the single indicator can be defined. For complex sustainability assessment, aggregation of data on two additional levels was used (excluding indicators) (Figure 5):

- company level – designated as x_c,
- separate Pillar of sustainability level – designated as x_{econ} for economy, x_{eco} for ecology, and x_{soc} for people.

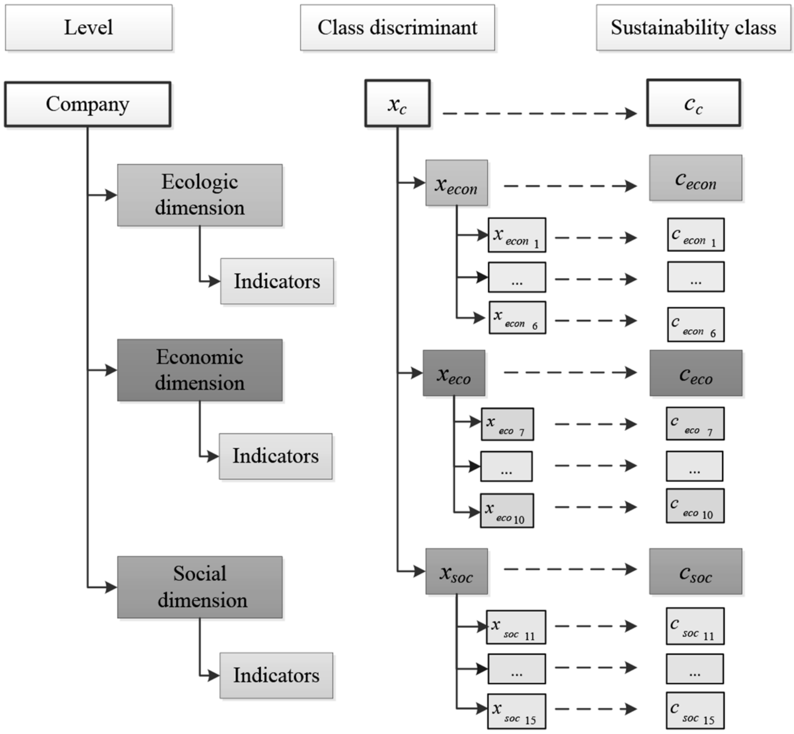

Figure 5. Levels of data aggregation during sustainability classification according to SAM.

SME can be assessed from the perspective of each sustainability pillar as well as for the whole company. The initial calculation of class discriminant is made on the level of indicators. Each value of the class discriminant (x) corresponds to the appropriate sustainability class (c). Information about the class of the indicator has considerable influence on prioritizing the actions that are needed to improve the assessment class of the company. After assessment at the indicator level, the calculated aggregated discriminants of each pillar of the sustainable development and the company are calculated.

In order to identify the sustainability class of the company, an aggregate class discriminant needs to be calculated (Eq. 11) (Kosacka et al., 2015):

$$x_c = \frac{x_{eco} + x_{econ} + x_{soc}}{\sum \eta_i} \quad (11)$$

Where x_{eco} sustainability class discriminant of the ecological aspect of sustainability, determined by the indicators related to the environmental pillar of sustainable development (Eq. 12):

$$x_{econ} = \frac{\sum x_{i_{eco}}}{\sum \eta_{i_{eco}}} \tag{12}$$

x_{econ} is the sustainability class discriminant of the economy aspect of sustainability, determined by the indicators related to the economy pillar of sustainable development (Eq. 13):

$$x_{econ} = \frac{\sum x_{i_{econ}}}{\sum \eta_{i_{econ}}} \tag{13}$$

x_{soc} is the sustainability class discriminant of the social aspect of sustainability, determined by the indicators related to the social pillar of sustainable development (Eq. 14):

$$x_{soc} = \frac{\sum x_{i_{soc}}}{\sum \eta_{i_{soc}}} \tag{14}$$

In order to make SAM more user friendly, a simple spreadsheet was prepared – Sustainability Assessment Card (SAC), which shows information about the sustainability class at three levels of details (Figures 6 and 7).

SAC		
No	Indicator Name	Real value
1	OEE	
2	RPF	
3	Planning adequacy	
4	AMT	
5	Level of executed orders	
6	OOS	
7	ECL	
8	WGL	
9	MRR	
10	GEL	
11	Employment	
12	Staff training	
13	HRPP	
14	Comfort level	
15	Innovation level	

Figure 6. Sustainability assessment card – basic sheet.

At the beginning, the card shows a basic window with all indicators used in SAM and *"Real value"* cells where the real value of each indicator should be placed. In the result calculated automatically by the spreadsheet, information about the sustainability class at the level of the company and each sustainability dimension will be highlighted. There is one more option – *"Improvement potential"* that shows information about the improvement direction plan and its priorities.

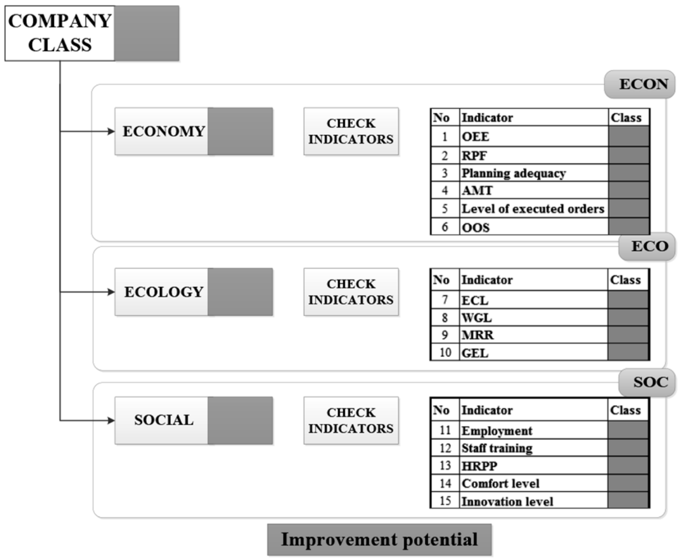

Figure 7. Sustainability assessment card – final results.

The user is shown information about the sustainability class as well as the improvement potential list describing where and in what priority actions should be taken. The procedure of the establishing the improvement potential is presented in the Figure 8.

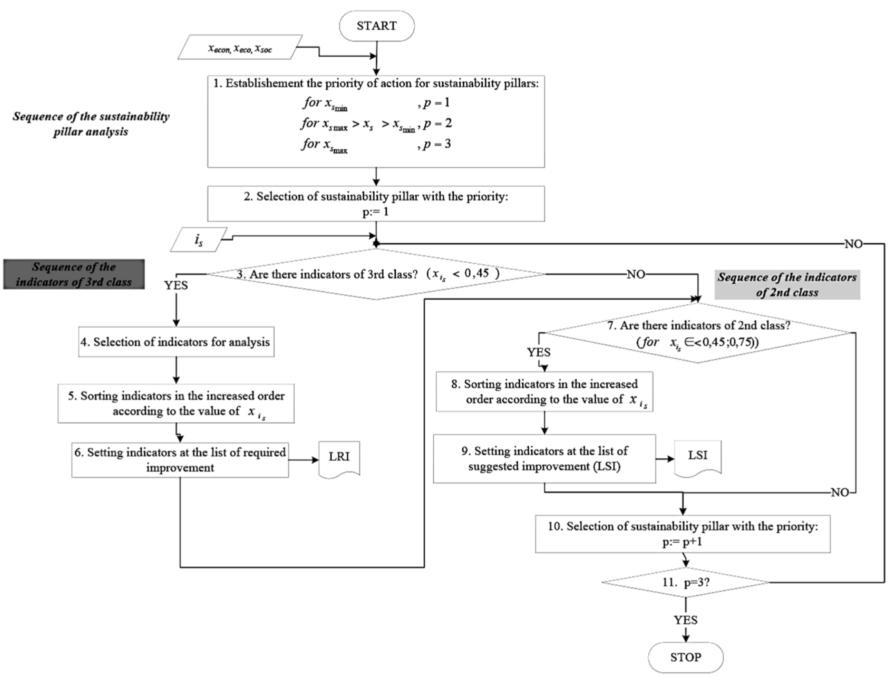

Figure 8. Improvement potential establishing algorithm.

At first, the priority status of the corrective actions according to the sustainability pillars is established. The selection is based on the value of the class discriminant x_s, where s means the sustainability pillar, *s ϵ{econ, eco, soc}*..

In a subsequent step, indicators are chosen (from analyzed sustainability pillar) that represent the third class of sustainability; these are sorted in increasing order into the *"List of required improvements action"* (LRI). These actions should be taken immediately to improve the values of particular indicators. Simultaneously, the *"List of suggested improvement action"* (LSI) is built; these are pointed indicators for improvement, if there are organizational and economic possibilities.

The basic rule of establishing priorities is the improvement action priority list: *"The lower value of the class discriminants, the higher priority of improvement action"*.

To improve the tool, we plan to develop an *"Improvement potential"* so as to offer not only the direction of improvements, but also a list of specific activities dedicated to each indicator aimed at improving the sustainability class.

RESULTS

The proposed method of sustainability assessment was pilot tested in three Polish remanufacturing companies, representing SMEs. The sample was intentionally limited to three companies because of the sustainability assessment in companies with predefined organizational characteristics.

First, real values of indicators are calculated (Table 4).

Table 4. Real values of indicators (based on Golinska et al., 2014).

Indicator	Company 1		Company 2		Company 3	
	Real value	i_r	Real value	i_r	Real value	i_r
OEE	90%	0,9	78%	0,78	58,31%	0,58
RPF	5	0,9	4	0,7	3	0,5
Planning adequacy	60%	0,6	35%	0,35	1%	0,01
AMT	4	0,7	4	0,7	3	0,5
Level of executed orders	97%	0,97	92%	0,92	90%	0,9
OOS	4	0,7	3	0,5	1	0,1
ECL	1	0,9	2	0,7	3	0,5
WGL	5%	0,95	10%	0,9	17%	0,83
MRR	95%	0,95	90%	0,9	85%	0,85
GEL	1	0,9	3	0,5	3	0,5
Employment	120%	0,996	100%	0,995	90%	0,995
Staff training	75 %	0,75	50%	0,5	30%	0,3
HRPP	8	1	40	0,8	150	0,6
Comfort level	30%	0,3	30%	0,3	10%	0,1
Innovation level	75%	0,75	40%	0,4	30%	0,3

Table 4 presents the values of the indicators after relativization (i_r). After inserting data to the SAC, information can be obtained about the sustainability class at different levels of detail. Table 5 presents summarized results of the sustainability class at the level of the company, as well as sustainability dimensions.

Table 5. Sustainability classification for three remanufacturing companies.

Sustainability assessment level	Company 1	Company 2	Company 3
Company class (c_c)	1	2	2
Economy (c_{econ})	1	2	3
Ecology (c_{eco})	1	1	1
Social (c_{soc})	2	2	2

The sustainability class at the company level provides an overall assessment of the current situation, but only as very general information. While it enables companies to be compared, the information is not efficient to take improvement actions. From the analyzed companies, Company 1 is at the best level of sustainability (class 1 at the company level). To support decision makers, the analysis should be extended to the level of indicators. It is necessary to verify the values of classes at the level of indicators, because of the application of data aggregation (at the level of the company and sustainability dimension).

The next part of the paper will describe the results for Company 1 (analysis for other companies would be the same). Inserting the real values of the indicators in SAC obtains the following results (Figure 9):

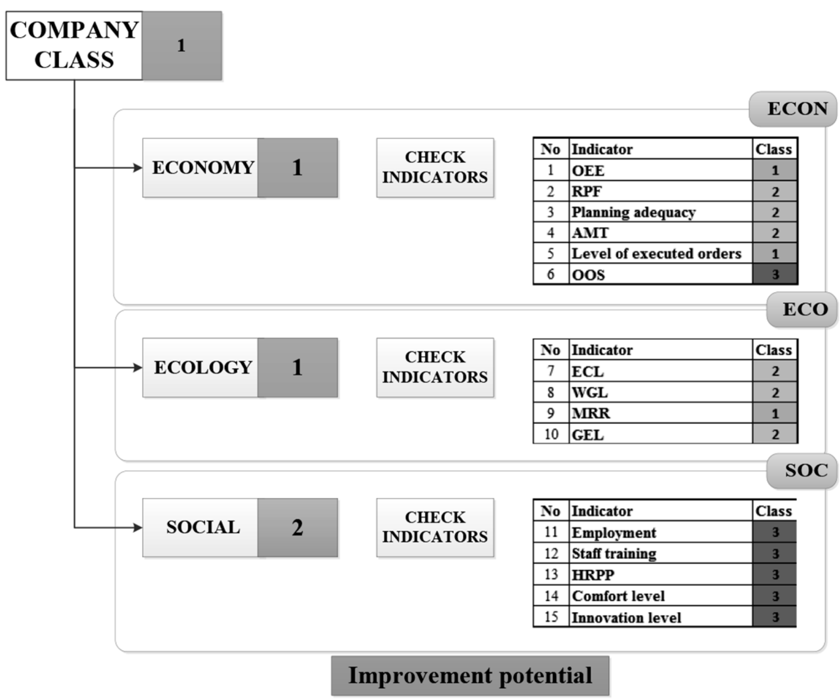

Figure 9. SAC for Company 1.

The analyzed company achieves a very high sustainability class from the perspective of the economic and ecologic dimension (class:1); in the social dimension, the results are 2^{nd} class. In order to achieve a higher level in the social dimension, we need to look in-depth at the particular indicator levels. According to the executed analysis, lists of improvement potential were achieved – LRI (Table 6) and LSI (Table 7). For the LRI, the authors have proposed corrective activities that should be introduced immediately.

Table 6. List of required improvement actions with proposed corrective activities.

Priority	Indicator	Example of corrective activities
1	Comfort level	Reorganizing the workplace to minimize the distance between them. 5S at the workplace
2	Staff training	Internal training by other staff
3	HRPP	Providing protective clothing for employees Automation of harmful processes (e.g., painting)
4	Employment	Internships Employing people with disabilities
5	Innovation level	Idea box for workers Award for interesting ideas
6	OOS	Encouraging people for returning worn-out products (advertisement) Taking part in fairs

All presented indicators require immediate corrective actions. Table 6 also describes examples of improvement activities that might help to improve the values of the indicators that achieve the individual value “2”.

Table 7. List of suggested improvement actions.

Priority	Indicator
1	AMT
2	Planning adequacy
3	RPF
4	GEL
5	WGL
6	ECL

The presented method helps decision makers of SMEs in the remanufacturing sector make improvements to achieve a better sustainability class.

DISCUSSION

The presented method allows the complex assessment of sustainability in SMEs from the remanufacturing industry. It helps to classify and compare companies with the use of a specific system of indicators. The main advantage of the method is ensuring the comparability of qualitative and quantitative indicators, which are commonly used in the assessment of SMEs. This method allows the inclusion in the assessment of not only numerical data, but also the expert knowledge of management. SAM supports decision makers in the context of sustainability improvement. It is an easily applicable decision support method for analyzing and implementing appropriate actions for increasing sustainability class. Effects of SAM implementation can be seen from the perspective of each remanufacturing company, as well as on the level of the whole economy (national and global). The company benefits from guidelines on what to improve to become more sustainable, which is of significant interest these days.

The unique value of the method is its assessment of sustainability in remanufacturing companies. Researchers have found a paper that determines the sustainability maturity level of a remanufacturing company (Golinska and Kuebler, 2014). However, research is limited on the issue of sustainability assessments for remanufacturing companies that can classify the companies and support decisions to improve them. Papers are available that assess remanufacturing products (e.g., alternators in Schau et al., 2011).

CONCLUSION

The paper aims to present the development and application of a Sustainability Assessment Method (SAM) designed by the authors. The method is dedicated to small and medium sized enterprises in the remanufacturing sector. SMEs in the remanufacturing sector very often lack advanced non-financial reporting systems or procedures. The authors, based on their previous experience and case studies conducted in SMEs in the remanufacturing sector, proposed a set of universal indicators that can be assessed with the expert knowledge of a decision maker, without need for an extensive reporting effort.

The main advantage of the SAM is its flexible framework, which allows for the inclusion in the assessment of both qualitative and quantitative indicators. The method first assesses the current situation regarding sustainability resource utilization in everyday operations, the so-called sustainability level of the company. The proposed simple tool helps to identify the areas that need improvement. Finally, the SAM and its associated tool help to prioritize improvements that should be taken.

The limitation of this method is its focus by SIS definition on the characteristics of remanufacturing SME, especially in the automotive sector. Further research will include the extension of the method to incorporate individual sustainability indicators that might be crucial for a particular company.

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