Value Stream Mapping and Process Indicators Supporting Sustainable Development in Organizations – A Systematic Literature Review

Ewelina Wyczewska[1(✉)] and Dorota Stadnicka[2]

[1] Doctoral School of the Rzeszow University of Technology, Al. Powstancow Warszawy 12, 35-959 Rzeszów, Poland
d511@stud.prz.edu.pl

[2] Rzeszow University of Technology, Al. Powstancow Warszawy 12, 35-959 Rzeszów, Poland
dorota.stadnicka@stud.prz.edu.pl

Abstract. The concept of sustainable development (SD) is gaining more recognition and the chosen SD goals are being implemented in enterprises. Until recently, organizations focused mainly on the economic aspect. Currently enterprises, when determining strategy, performing risk assessment and mapping processes using the VSM (Value Stream Mapping) tool, are increasingly making efforts to incorporate both ecological and social aspects. When defining their mission, vision and goals, enterprises cannot forget to specify indicators which act as a key signpost to business development. The indicator setting is based on SMART methodology and only sporadically is there a reference to SD goals. For monitoring purposes and in order to react quickly enough to process disruptions, enterprises are encouraged to collect data automatically. This will lead to lower level of defective products which have negative impact not only on the environmental but also on the economic aspect.

In practice, many articles have been published on VSM and the impact of indicators on aspects of SD. The systematic review of the literature, which was carried out in this paper, confirms that the authors sought evidence of what indicators support SD. The systematic review of the literature performed according to the established research methodology, includes identification of research questions, identification of keywords, selection and exclusion criteria, and analysis of results.

The main aim of this article is to obtain information on what indicators are currently in use in enterprises, and then to link them with the SD aspect. The collected input data will be used to develop a model for assessment of the impact of enterprise processes on SD. Following a consultation with experts, an attempt will be made to develop a model serving as a tool supporting small and medium sized enterprises.

Keywords: Value Stream Mapping · Sustainable Development · Systematic Literature Review

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1 Introduction

Value Stream Mapping (VSM) is a tool for the identification of waste, which helps to recognize and understand the flow of both materials and information on the product's way in the value stream [1]. The analysis makes it possible to identify wasteful activities (NVA = Non-Value Added) and activities with added value (VA = Value Added). Thanks to this analysis, it is easy to determine the actual areas requiring improvement, and with the use of supporting tools, to carry out a detailed analysis leading to the root cause. The literature has demonstrated that Lean tools provide the key strategy to streamline production processes and allow for prompt adjustment to ever-changing market requirements [2]. In order to actively participate in the process of continuous improvement, enterprises should follow the set rules of SD. Sustainable development is a vision of changes designed to set a course for, among others, the development of small and medium-sized businesses aiming to improve their economic, environmental and social aspects. Sustainable development requires appropriate and intentional shaping of the relationships between economic growth, care for the environment (primarily natural environment) and fulfilment of various human needs [3]. Works related to value stream mapping that take into consideration not only economic but also environmental and social aspect are present in literature. For example, the works [4] and [5] present a Sus-VSM method which can be applied to assess the three aspects with the use of the proposed indicators. However, the method is complex and require much data to perform the analysis. Also, in the work [6] the authors applied VSM methodology with so called green aspects to identify wastes. But this time the data related to environmental and social aspect are not visible on the map. The same situation is in the case of the work [7]. The authors of this paper found the analysed approaches unsatisfactory, which was the main reason for undertaking the analysis presented in this research. The aim of this paper achieved through the systematic literature review that has been carried out to show the interest in the presented topic, what attempts to develop the model have been undertaken so far and what indicators are currently applied by enterprises.

2 Research Goal and Methodology

2.1 Research Objectives and Questions

This section presents the goal and methodology of the research. For the purpose of this paper, the following research goal has been set: Finding research gaps in implementing of the VSM tool and indicators helping with improvement of aspects of sustainable development, which will consequently allow to propose a model supporting sustainable development. The model will take into account the selected, and thus the most relevant, processes in the production area, and their course of development which will be monitored using the proposed indicators.

To achieve this goal, the following research questions have been put forward:

RQ1: In which **industries and processes** is VSM used?

RQ2: What **indicators** are used to assess Sustainable Development?

In this paper the following methodology was used: Identification of keywords and adoption of search rules (Step 1), Identification of databases (Step 2), Adoption of selection criteria and a search for articles (Step 3), Adoption of exclusion strategy for publications (Step 4), Quantitative analysis (Step 5), Qualitative analysis (Step 6), Discussion (Step 7), and Conclusion (Step 8).

2.2 Identification of Keywords and Adoption of Search Rules (Step1)

A systematic review of the databases has been carried out on the basis of selected keywords and their modifications. The main keywords are *Value Stream Mapping, Sustainable development* and *Manufacturing*. The modification of the keywords used in the search process is shown in Table 1. The keywords were used to create the search rules (Table 2). In the first search, it was decided to select only the articles connected with Value Stream Mapping. The second search concerned sustainable development. The purpose of the third search was to see whether VSM is connected with SD in selected publications. The last search concentrated on VSM and SD in production areas.

Table 1. A set of keywords and their modifications.

Keyword 1	Keyword 2	Keyword 3
Value Stream Mapping	Sustainable Development	Manufacturing
Value Stream Map	Sustainability	Production
Value Stream	Sustained Development	
	Sustainable-Development	

2.3 Identification of Databases (Step 2)

The research was based on the following databases which were chosen to search publications relating to the analysed subject: *Web of Science and Scopus.* The focus was solely on these databases due to their access to the majority of publications containing keywords provided in Table 4.

2.4 Adoption of Selection Criteria and a Search for Articles (Step 3) and Adoption of a Publication Exclusion Strategy (Step 4)

Firstly, the titles of publications, keywords and abstracts were searched for, and the obtained results were summarised in Table 3. The number of searched articles in each database is presented in Table 4.

Table 4 proves that VSM and SD are currently widely discussed in the literature. However, on the basis of the collected data, it can be recognized that SD combined with

Table 2. Search rules.

Keywords combination	Search rules
Search 1: VSM	("Value Stream Mapping" OR "Value Stream Map" OR "Value Stream")
Search 2: SD	("Sustainable Development" OR "Sustainability" OR "Sustained Development" OR "Sustainable-Development")
Search 3: VSM + SD	("Value Stream Mapping" OR "Value Stream Map" OR "Value Stream") AND ("Sustainable Development" OR "Sustainability" OR "Sustained Development" OR "Sustainable-Development")
Search 4: VSM + SD + MP	("Value Stream Mapping" OR "Value Stream Map" OR "Value Stream") AND ("Sustainable Development" OR "Sustainability" OR "Sustained Development" OR "Sustainable-Development") AND (Manufacturing OR Production)

Table 3. Search places.

	Search places
Web of Science	Topic (Searches Title, Abstract, Author Keywords, And Keywords Plus)
SCOPUS	Title, Abstract, Keywords

Table 4. Results - number of papers found. The date of the data download: 03.04.2022.

	Combinations of keywords			
	VSM	SD	VSM + SD	VSM + SD + MP
Web of Science (WoS)	1 386	267 223	107	83
Scopus	2 594	402 230	198	135

VSM is not a commonplace. Exclusions and data selection were applied to the articles found using *VSM + SD + MP* search rule. The articles not covered by the scope of this research related to Construction Building Technology, Occupational Health, Chemistry or Medicine, were excluded from the further analysis. Moreover, only articles in English, namely published articles, conference papers or book chapters, were taken into account. Therefore, a set of papers analysed consisted of 60 papers from WoS and 123 papers from Scopus.

2.5 Quantitative Analysis (Step 5)

The results of the quantitative analysis are presented in Fig. 1 in Sect. 3.2.

2.6 Qualitative Analysis (Step 6)

The qualitative analysis aimed to find answers to the research questions stated in Sect. 2.1. The results of the analysis were to show what aspects of sustainable development are of the greatest interest, and in what areas researchers have demonstrated evidence of the VSM tool usage as well as indicators which facilitate the management and monitoring of the production area processes, in reference to sustainable development.

Section 3 presents results in the following categories:

- Quantitative identification of publications and the link with the production area,
- Qualitative identification of keywords for the purpose of obtaining information referring to the aspects of sustainable development, as well as VSM tools and supporting tools,
- Identification of indicators used to analyse sustainable development in the production area.

The research methodology was based on a detailed analysis of the full version of selected articles.

3 Result

3.1 Review of the Results

In this section, the results of the literature review are presented. Table 5 shows the results of the extraction.

Table 5. Exclusion strategy and data selection.

Strategy for choosing articles	No of publications	
	WoS	Scopus
Number of publications found	60	123
After elimination of duplicates	164	
After elimination of publications outside the scope of the research (after reading summaries)	152	
After elimination of publications for which the full text is not available	114	
After elimination of publications outside the scope of the research (after reading the full text)	86	

The total number of publications found in the literature relating to SD, VSM and the production area amounts to 164. After reading the full abstracts, 12 publications were rejected. 114 publications were subjected to an in-depth quantitative and qualitative analysis. Among the analyzed articles, 31 publications were assigned to the “General” category. It includes literary pieces which provide general review of the literature and refer to more than one industry, or do not specify in which industry the research was carried out. Ultimately, 86 publications met the keyword search criteria.

3.2 Qualitative Analysis of Publications

The first part of the quantitative analysis aimed to show how the work on sustainable development has evolved over the years. Figure 1 shows the number of publications through the years by type for 152 articles.

Since 2014, the researched subject matter has been attracting more interest, and the number of selected publications reached 19 articles in 2014 alone. This upward trend was visible for a number of years. For 2021 and 2022, no significant number of publications have been found disproving the continuity of research interest in this topic.

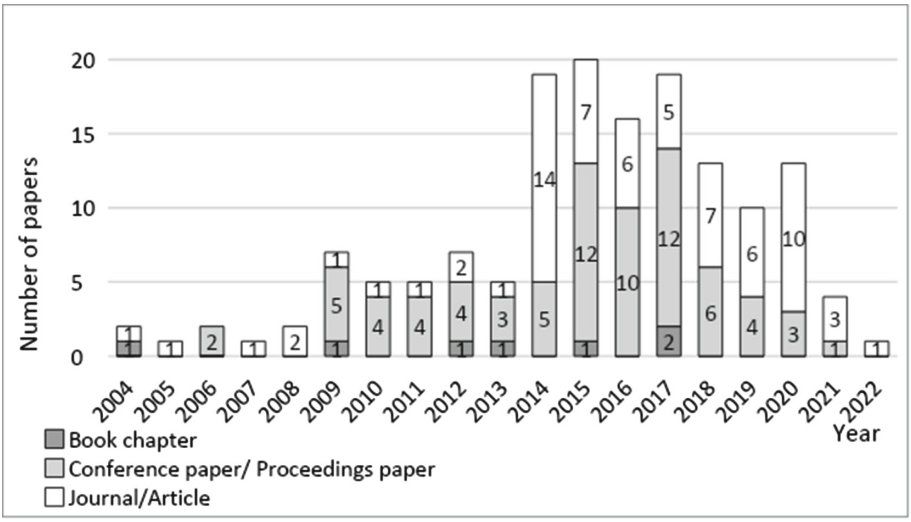

Fig. 1. Number of papers in years by type.

In 36% of the publications, the authors presented a practical application of the VSM tool, in reference to the specific industries. The collected results are shown in Fig. 2.

Figure 2 shows that the automotive industry has been of the greatest interest with 14 publications. Other industries analysed in relation to sustainable development are: steel (5 articles), building (4 articles), electronics (3 articles), food (3 articles), chemical (2 articles) and packaging (2 articles). The remaining articles were included in the General group with approximately 64% of the overall publications subjected to an in-depth analysis. Within this percentage, there are single cases for the following industries: Electrical Appliances, Alcohol, Sugar, Aluminium, Aviation, Brass, Dairy, Electrical, Electrotechnical, Fish, Flooring, Furniture, Mechanical, Paper, Pharmaceutical, Plastics, Printing, Railway, Service, Education, Stonemasonry and Tailoring.

In addition, within this group there is literary work analysing theoretical aspect of sustainable development and the articles, which do not mention any specific industry or refer to a larger group of industries.

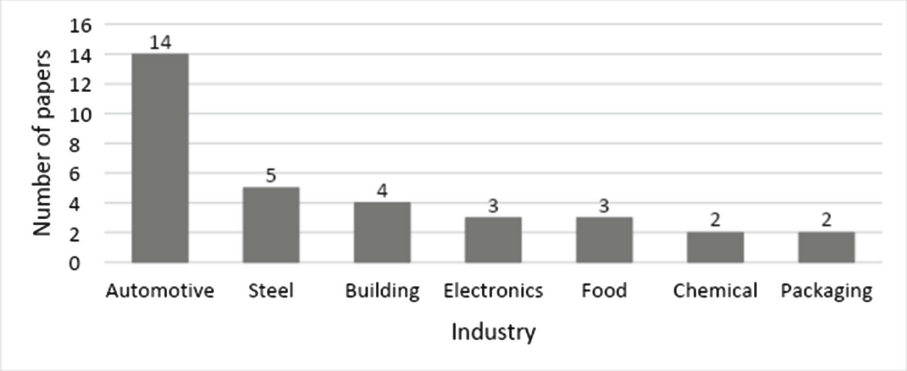

Fig. 2. Number of publications per industry.

3.3 Quantitative Analysis of the Author Keywords

The quantitative analysis of the publications was intended to show how the work on sustainable development has evolved over the years.

The analysis of keywords, specified by the authors of publications, was performed for 152 articles (see Table 5). For obvious reasons, the list of these articles has not been included in the list of bibliography of this paper, but the detailed description of the procedure allows it to be repeated.

In total, 394 different author keywords were identified in these 152 papers. In the VSM category, 25 synonyms relating to VSM were recognized, including, among others, Dynamic value stream mapping, Economic value added, Energy Value Stream Map, Environmental Value Stream Mapping, Green value stream, Sustainable value stream mapping, Value chain, Value-value load diagram, LCA-based energy value stream map, Sus-VSM. Value stream mapping, featuring in 32 publications, was the most frequently occurring keyword in the articles. The use of synonyms shows efforts to extend the standard VSM map to other aspects of sustainable development.

In the Sustainable Development category, 11 synonyms were identified, e.g. Sustainable Production, Sustainable operations, Sustainable development, Sustainable manufacturing, Sustainability, Organizational sustainability, Sustainable growth, Sustainable development. In the Manufacturing category, 30 keywords were assigned to two groups: Industry and Process, e.g. Process industries, Manufacturing industry, Industry 4.0, Manufacturing process, Production process and Assembly.

3.4 Qualitative Analysis of the Author Keywords

The qualitative analysis was done by assigning the author keywords to one of the 22 defined categories. The categories were defined by the authors of this work as well as they assigned the keywords to the categories. As it was already mentioned in the previous section the analysis of keywords, specified by the authors of publications, was performed for 152 articles (see Table 5). The results of the author keywords grouping are shown in Table 6. The table presents the total number of publications relating to the specified group of keywords.

Table 6 demonstrates that in the first three categories referring to *SD, ecological aspect* appears to be the most popular, whereas the other aspects of sustainable development, namely economic and social, are of secondary importance. In the category named Ecological aspects, 28 keywords were defined and the evidence of referencing to the discussed topic was found in 38 published articles. The keywords appearing in this category are, among others, Green manufacturing (7 articles), Carbon footprint (5 articles), Environmental management (4 articles), Cleaner production (3 articles).

In the *Sustainability* category, there were 11 keywords and the evidence of reference to the researched topic was noted in 35 articles.

Table 6. Groups of keywords.

Group	No of different keywords in the group	No of different papers in the group
1. Economic aspects	11	8
2. Ecological aspects	28	38
3. Social aspects	12	11
4. Principles, methods and tools	81	82
5. Wastes	16	14
6. Continuous improvement	9	12
7. Performance parameters/indicators	46	41
8. Simulations	5	6
9. Networks, supply chain management and value stream	18	18
10. Live cycle analysis	9	7
11. Processes	12	11
12. Products	5	4
13. Systems	56	81
14. Work organization	7	6
15. Design	6	5
16. Industry	18	20
17. Company size	4	5
18. Case study	2	2
19. Manufacturing/Production	4	5
20. Sustainability	11	35
21. Lean	8	7
22. Others	16	11

In the *Performance parameters/ indicators* category, 46 keywords were counted and references to the subject were found in 41 articles.

3.5 Indicators – A Qualitative Analysis of Full Texts

The articles discussed a variety of indicators relating to ecological, economic and social aspects as shown in Table 7.

Table 7. Performance parameters/indicators applied to analyse ecological, economic and social aspects in the reviewed works. Numbers presented in the table refers to ID of the paper. Source file with the coded papers list available upon request (86 papers).

Performance parameters/indicators	Sustainable development		
	Ecological aspects	Economic aspects	Social aspects
Cycle time	25	25	-
OEE	-	2	-
Takt time	25, 95	25, 95	-
Single score index	-	3	-
Sustainability index	78	78	-
Sustainability indicators	85	13, 85	85
Improving energy efficiency	-	86	-
Industrial energy efficiency	-	86	-
Eco-efficiency	33	-	-
Efficiency	88	-	-
Environmental performance	12, 18, 79	12, 79	-
Material efficiency	89	-	-
Resource efficiency and sustainability	63	-	-
Green productivity	78	78	-
Sustainability performance	9	9	-
Sustainability assessment	9, 74	9	-
Manufacturing sustainability assessment	3	3	3
Manufacturing Process Excellence	-	96	-
Goals	-	28	-
Organizational goals and metrics	-	28	-
Metrics	92	-	-
Performance	-	106	-
Performance management	-	68	-
Business performance	-	143	-
Criteria	-	120	-

(*continued*)

Table 7. (*continued*)

Performance parameters/indicators	Sustainable development		
	Ecological aspects	Economic aspects	Social aspects
Critical success factors	-	150	-
Domestic market performance	-	138	-
Effectiveness	-	147	-
Export performance	-	138	-
EXPERF	-	138	-
Global performance	-	120	-
High performance	-	137	137
ILL index (indicators of Innovativeness, Learning and Lean indices)	-	138	-
Key behavioural indicators	-	-	130
Measurement	-	-	152
Performance and impact	-	-	130
Performance assessment	-	-	123
Performance measurement	-	131	-
Performance measures	-	156	-
Project evaluations	-	127	-
Self-assessment	-	121, 131, 138	152
Assessment	-	-	137

Table 7 demonstrates that, in the category Performance parameters/indicators, mainly the ecological aspect was of great interest. As many as 32 keywords have been assigned to this category. Only two keywords, i.e. Sustainability indicators and Manufacturing sustainability assessment occurred simultaneously in the three analysed aspects.

3.6 Models – A Qualitative Analysis of Full Texts

The models subsection presents a short summary of the models developed so far in the examined production area, with reference to the three aspects discussed: ecological, economic and social (Table 8). The main goal of this analysis was to see how different works cover the three sustainability aspects.

Table 8 shows that much attention has been paid to the research on Business Excellence, which includes the EFQM Excellence Model, the Baldrige Model, ISO standards, GRI, and examines its integration with Corporate Sustainability [8]. Despite the existence of better frameworks for evaluating sustainable development of an enterprise, Business Excellence models (BEM) have proven to provide a suitable performance measurement

Table 8. Models applied to analyse ecological, economic and social aspects in the reviewed works. Numbers presented in the table refers to ID of the paper (86 papers).

Models / Methods	Sustainable development		
	Ecological aspects	Economic aspects	Social aspects
SEM (Structural equation modelling); Structural equation models	79	79	157
Enterprise modelling	70	70	-
4P excellence model	-	-	149
Business Excellence Models	139, 151	139, 151	139, 149
EFQM Excellence Model (European foundation for quality management model	-	118, 127, 143	114, 119, 137, 144, 149,152
Excellence Model	-	138	117, 130, 134
Growth management model	-	-	119
Malcolm Baldrige model	-	-	119
Models	-	158	158
Quality models	-	-	119
Shingo Operational	-	-	155

framework for integrating sustainable development of a company. Nevertheless, the business criteria remain vague and ambiguous, failing to clearly specify how to measure a company's sustainability performance. The study provides a general approach to examining the suitability of BEM for accommodating corporate sustainability development. The scope of the study is limited as some organizations display specific levels of maturity in both BEM implementation and corporate sustainable development. Further research examines the suitability of current economic systems for achieving corporate sustainable development, and the use of lean-six sigma methods to support corporate sustainable development at the strategic and operational levels.

3.7 Waste – A Qualitative Analysis of Full Texts

In the subsection Waste, 14 articles relating to waste were analysed. Table 9 summarizes the results achieved. The main goal of this analysis was to identify the types of wastes analysed in different papers to see if they are related only to economic or also to environmental and social aspects. In the same time, the methods applied in the reviewed papers and used indicators were identified.

Based on Table 9, six types of waste were identified. Waste refers to, among others, issues related to the production and ill-management of waste. This matter is not just about waste in terms of materials but also about problems relating to energy consumption, water consumption, pollution emission or unnecessary transport of materials and goods [7].

Table 9. Performance parameters/indicators applied to analyse ecological, economic and social aspects in the reviewed works. Numbers presented in the table refers to ID of the paper (86 papers).

References	Waste under analysis	Used tools/ Methods	Indicators
[5–18]	Waste generation/ ill-management of waste Energy consumption Water consumption Material consumption and associated costs Unnecessary transportation of materials, goods and resources Pollution emission	VSM, Kanban pull system SIPOC Root cause analysis Waste flow mapping Environmental system analysis Value chain analysis Green lean Green waste Kaizen events	Takt time Cycle Times Material efficiency Sustainability performance

The process analysis was performed mainly using the VSM tool but other supporting tools have also been utilized, e.g. Kanban pull system, SIPOC [9], Root cause analysis [10] or Environmental system analysis [11]. In a small number of cases, indicators were assigned to facilitate monitoring of the work carried out, e.g. Material efficiency [11], they also provide evidence that organisations are trying to move towards sustainable development.

4 Discussion

4.1 Industries and Processes where VSM is Used

In the first question, we asked about the industries and processes in which the VSM tool was used to optimize the process. Figure 2 shows that among scientific publications, the automotive industry has generated the greatest interest. Evidence of the practical application of the VSM tool can be found mainly at assembly stations in production areas, but also in the supply chain area. The obtained results are absolutely correct, because one of the stages of process mapping is to identify stock levels before the process starts, so it is possible to develop a plan for managing stocks in the warehouse and during production in an economical way. The conducted research shows that in the case of the automotive industry, publications mainly refer to the economic aspect. The production processes of the automotive component were subjected to a deeper analysis [12, 13] such as the vehicle frame production process [14] or bumper production [6].

In the Steel and Building industry, we can also find a reference to the ecological aspect. Lifecycle product is frequently mentioned in articles, as in the case of iron and steel products [15]. This fact does not come as a surprise to us, because the European Union requirements put more and more emphasis on companies in terms of reducing the consumption of materials, raw materials, etc. and thus enforce the use of alternative technologies that meet the guidelines of sustainable development. This is discussed in one of the articles describing the certification of buildings using international

certification systems, i.e. LEED (Leadership in Energy and Environmental Design), BREEAM (British Research Establishment Environmental Assessment Method) and DGNB (Deutsche Gesellschaft für Nachhaltiges Bauen) [16].

4.2 Indicators Used to Assess SD and Related Wastes

In the second question, we asked about the indicators that are used to assess Sustainable Development. A reference to the three discussed aspects, used at the same time, was only found in two articles.

The Sustainability indicators mentioned in Table 7 have been cited in relation to the qualitative assessment of the Delphi-analytical hierarchy process (AHP) method and quantitative analysis sustainable-value stream mapping. Delphi method is used to select the appropriate indicators and determine value using the efficiency approach [17].

The parameter mentioned in Table 7, the Manufacturing sustainability assessment, was quoted in relation to the operation management model, developed in response to changes in society's requirements such as better working conditions, clean production, recyclable and reusable products and improved social conditions [19].

5 Conclusions and Future Work

The quantitative and qualitative review proves that lean methods and tools help manufacturing organizations achieve operational excellence. And thus meet both traditional and modern organizational goals, such as profitability, efficiency, responsiveness to changes, increasing product quality and customer satisfaction [20]. In order to demonstrate these advantages, it is important to properly formulate indicators to produce a measurable result.

The literature review shows that an attempt has been made to develop a model supporting sustainable development, and there are companies that have taken up the challenge of progressing towards sustainable development [17]. However, most of the work on developing the model does not take into account all three aspects at the same time, of which the social aspect is most often overlooked [21]. It has also been noted that enterprises monitor production processes using indicators, however do not verify the dependent impact on each aspect separately.

The aim of this paper was to analyse the interest in the presented topic, the models that have been under-taken so far and indicators that are currently used in the context of sustainable value stream analysis. The performed analysis and the obtained results may contribute to the development of a model for assessing the impact of company processes on sustainable development.

The results achieved demonstrate that it is reasonable to continue research and attempt to develop a model that will realistically focus on all significant aspects of sustainable development, will take into account the impact and interdependence of aspects, indicate the direction of development for an organization as well as improve aspects of sustainable development in order to make it possible to implement in small and medium-sized enterprises in every industry.

The authors see the needs to extend the research in the future works by searching for other models that are not directly related to value stream mapping but they support sustainability assessment and may be useful in the development of a model valuable for industry.

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