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Research paper

Application of SWOT analysis in construction waste management – usefulness of the 5S and VSM methods

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Abstract: Recently, more and more attention has been paid to the management and organization of work and production in enterprises of various industries. Great emphasis is placed on reducing the waste of raw materials, improving productivity, and minimizing the huge amounts of waste generated, which is part of the concept of sustainable development. Every year, the construction sector produces 30% of global waste, which poses a big challenge in terms of recycling and disposal, especially in countries that do not have sufficient financial resources and technological capabilities. Implementing appropriate lean methods into the construction sector is therefore an opportunity to eliminate existing problems. This study presents a literature review, which is the basis for identifying two most frequently used lean management tools that can help reduce the amount of waste generated. The aim of the article was to assess the possibility of their application in the construction sector using SWOT analysis. Based on the research conducted, it was shown that in order to obtain the greatest benefits from the use of 5S and VSM methods, the most beneficial strategy to adopt in a construction company will be an aggressive strategy (maxi-maxi). A significant barrier to the implementation of these tools is the lack of appropriate knowledge resources and technological limitations, especially in small and medium-sized enterprises. Moreover, it was shown that over the years 2013–2024, the number of publications and interest in lean in construction systematically increased, which confirms the usefulness of these methods for the construction sector.

Keywords: 5S practices, construction sector, construction waste, lean management, SWOT analysis, value stream mapping

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1. Introduction

The construction industry is one of the best-developing economic sectors in recent years. However, due to the strong dependence on economic, social and legal factors, as well as the individual nature of the projects implemented, this sector is often exposed to various types of problems, including lack of financial resources to cover budget exceedances, untimely implementation of Pasławski planned projects, generation of huge amounts of waste, the problem of maintaining a high level of quality of products and services [1]. Moreover, the construction sector is characterized by a high level of accidents at work. In the article [2] the impact of lean tools on the level of safety in a metal producing organization was discussed, paper [3] presents the impact of digital technologies on improving occupational health and safety, and research on assessing the degree of implementation of safety management practices and their relationship with low accident rates were discussed in [4]. Accident events are influenced by, among others: faulty equipment and devices, problems with ergonomics in the workplace and lack of awareness of occupational health and safety issues [5]. In order to solve existing problems, modern management methods in the field of lean management (LM) are increasingly being implemented in construction companies [6]. This concept was initiated in the Japanese manufacturing sector – Toyota Production System. Its main goal is to eliminate all waste in every area of the company's operations while increasing the quality of the final product. There are 7 main sources of waste that generate loss of time, money and burden on the staff. These are: waiting (e.g. for material, documentation, employees, etc.), unnecessary transport (e.g. between departments, positions, buildings, etc.), unnecessary movement (concerning the movement of an employee from one place to another), over-processing (activities that have no impact on product and service quality), defects and shortages (e.g. incomplete documentation due to loss, defective product), inventories (final products made in excess of consumer demand), overproduction (e.g. surplus of semi-finished products in relation to processing capacity next position). Most of the indicated areas of waste have an undesirable impact on the environment. Excessive bureaucracy (commonly referred to as unnecessary paperwork) requires cutting down more trees, unnecessary transport generates air pollution, and non-compliance of manufactured products contributes to the waste of natural resources. Therefore, in the era of taking actions to protect the environment, the use of the LM concept in construction companies fits perfectly into the idea of sustainable development. The LM concept is based on five main principles: identifying value from the customer's perspective, mapping the value stream, continuous process flow, introducing a pull system and continuous improvement. These principles are universal and can be adapted in any economic sector, e.g. the automotive industry [7], custom production [8], prefabricated construction [9, 10] or manufacturing industry [11]. The most frequently used lean tools include: kanban, Kaizen, Just-in-Time, Poka Yoke, SMED, 5S method and Value Stream Mapping (VSM) [12, 13]. Due to the large selection of lean tools that can be used, it is important to be able to select the appropriate method to solve a specific problem. For this purpose, in studies [14, 15], the authors presented an algorithm allowing the selection of appropriate LM tools and techniques using the AHP method. What is important for business owners is the simplicity and low cost of implementing management techniques borrowed

from the production sector. Ease of use translates into the time needed to train employees, and the ability to obtain clear conclusions translates into the Pasławski speed of identifying the source of the problem and its elimination. However, financial outlays for implementing selected methods into the company's structure are also important. Taking into account financial issues and the level of complexity, the frequently chosen lean tool is the 5S technique and visual management tools [16]. These tools are easy to use and allow for waste reduction, which is an opportunity to reduce the level of waste generated. Despite many advantages, the lean concept is not always possible to implement, especially in small and medium-sized enterprises, due to certain limitations. These are mainly insufficient financial resources, gaps in management suport [17], insufficient knowledge [18, 19] and legal aspects. The problem of insufficient knowledge and lack of appropriate training in the field of lean was presented as the main barrier to the implementation of the concept in the Jordanian construction subsector in the study [20]. To obtain tangible benefits from the application of lean principles, you must have appropriate financial resources, a detailed Pasławski implementation plan in the enterprise structure and use the knowledge and experience of specialists qualified in this field. Otherwise, despite the many strengths of using lean tools, it may lead to situations that threaten the proper functioning of the company. The aim of the article was to assess the usefulness of implementing the 5S and VSM techniques in construction waste management using SWOT analysis.

2. Lean management tools in the construction industry

In the context of the construction industry, the LM concept is known as lean construction (LC). It is an essential element of the construction process in order to perform the intended task faster, better and cheaper, while minimizing the amount of waste generated [21, 22] and natural resources used [23], and even CO_2 emissions [24], which is part of the scope of activities for sustainable development. One of the main problems of the current construction sector are the huge amounts of waste generated as a result of construction, demolition and renovation works [25]. The article [26] focused on housing infrastructure and identified the main sources of waste, and the study [27] discussed the perspective of construction and demolition waste management in the context of the European sustainable development strategy. Their improper management results in a negative impact on the environment and has an undesirable impact on the economy [28, 29]. Every year, the industry contributes approximately 30% to the production of global waste, which is a big challenge in terms of recycling and disposal, especially in countries with certain financial and technological limitations. Estimates of the Building Performance Institute Europe show that every year as a result of renovations, modernizations and reconstructions in the European Union countries, approximately 500 million Mg of waste is produced. In Poland, the situation is presented by the estimates of the Central Statistical Office, where in 2022 12 018 000 Mg of construction waste was generated, with as much as 5 925 000 Mg of waste stored so far [30]. Environmental issues relate not only to the waste generated, but also to the use of natural resources. According to Urban Circularity data, in 2021 the consumption of natural resources amounted to over

100 billion tons on a global scale, of which about 50% was accounted for by the construction sector [31]. The topic of implementing lean tools in the aspect of environmental protection is an increasingly discussed issue. The study [32] presents the use of the lean management tool (SMED project) in the management system in a manufacturing enterprise, the use of lean manufacturing tools in the process of improving environmental management in manufacturing enterprises is discussed in the study [33], while the article [34] presents a detailed literature review regarding lean tools and lean construction. The study [35] identified the types of construction waste generated and presented alternative possibilities for their elimination using several existing lean tools. In order to reduce the exploitation of natural resources and increase the quality of the product, the Taguchi method was used to determine the impact of modifying cement mortars with rubber and cork waste [36]. To make the adaptation of lean techniques bring even greater benefits, the synergy of two management methods was developed: lean construction and agile management, which was discussed on the example of the construction of roads and concrete columns. Based on the conducted research, positive effects of implementing combined methods have been demonstrated, in the form of cost reduction and time losses [37, 38].

Market analysis shows that few construction companies use lean tools in practice, and the usefulness of these tools is less often analyzed for the construction industry than for other industries. Based on the analysis of SCOPUS database [39] data from 2013–2024, the number of publications found using the following keywords was obtained: "value stream mapping" – 327 publications, "5S tool" – 42 publications, "lean management" – 545 publications and "lean construction" – 298 publications (Table 1). The results obtained refer only to the Member States of the European Union. The "–" sign means that there is insufficient information about publications from a given country in the analyzed database.

Table 1. List of the number of publications by keywords in the European Union member states in 2013–2024

EU Member State	Keywords			
	Value Stream Mapping	5S tool	Lean Management	Lean Construction
Austria	16	–	11	1
Belgium	7	1	11	–
Bulgaria	–	–	–	–
Croatia	4	–	8	–
Cyprus	–	–	3	–
The Czech Republic	11	1	15	1
Denmark	9	–	8	27
Estonia	4	–	1	3
Finland	6	–	20	69

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EU Member State	Keywords			
	Value Stream Mapping	**5S tool**	**Lean Management**	**Lean Construction**
France	7	–	39	10
Germany	86	–	108	66
Greece	5	–	3	1
Hungary	1	–	10	1
Ireland	8	1	6	15
Italy	34	–	76	26
Latvia	3	–	1	1
Lithuania	1	–	1	–
Luxembourg	4	1	2	3
Malta	–	–	–	–
Netherlands	9	–	29	5
Poland	**32**	**6**	**82**	**12**
Portugal	28	16	30	7
Romania	–	3	11	–
Slovakia	6	3	13	2
Slovenia	1	–	–	2
Spain	24	9	40	33
Sweden	21	1	17	13
SUM	**327**	**42**	**545**	**298**

According to the data, most studies in the assumed time period concerned issues related to "lean management" and the largest number were published in Germany (108 publications), in Poland (82 publications) and in Italy (76 publications). The fewest publications were recorded in the area of the 5S method, of which most works were published in Portugal (16 publications). It is worth noting the high publication rate in the area of value stream mapping, with most works in this field published in Germany (86 publications), and the least in Lithuania, Hungary and Slovenia – 1 publication. Topics related to the combination of construction and lean management principles, i.e. the concept of lean construction, were most frequently discussed in Finland (69 publications) and Germany (66 publications), and least frequently in Austria, the Czech Republic, Greece, Hungary and Latvia (1 publication each). It was noted that the analyzed issues were most often undertaken in specific EU Member States: Germany (260 publications), Italy (136 publications), Poland (132 publications), Spain (106 publications), Finland (95 publications) and Portugal (81 publications). The percentage share of Polish publications in the analyzed time period, taking into account the assumed

keywords, is shown in Fig. 1. According to the results obtained, over 62% of the studies concerned the subject of lean management, and only 4.5% of the 5S method. It is worth noting that Polish authors publish on the concept of lean construction, which is reflected in the indicator of 9.1%.

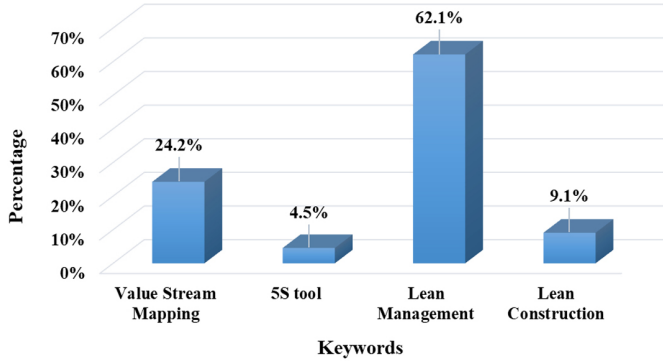

Fig. 1. Percentage of Polish publications from 2013–2024, including keywords

3. Characteristics of the 5S and VSM methods

The 5S method is an effective tool for better organization of the workplace. It allows you to create optimal working conditions with low financial outlays based on 5 aspects:

- Seiri (sorting) – concerns appropriate preparation of the workplace by removing unnecessary tools,
- Seiton (systematics) – organizing the necessary tools, assigning work, arranging equipment,
- Seiso – cleaning at the workplace,
- Seiketsu – standardization of introduced procedures,
- Shitsuke – discipline that enables maintaining the introduced rules.

Constant sorting of tools at the workplace and segregation of waste generated allows for added value in terms of the environment. Therefore, the implementation of 5S principles is an important tool to reduce the amount of construction waste generated and can improve activities related to the mandatory segregation of waste by type by companies under legal regulations. Entrepreneurs using the 5S method have a chance to increase the work efficiency of their employees, mainly as a result of creating a more ergonomic work station, which results in a shorter product production process and reduces the risk of accidents. Thanks to this, the quality index of products and services also increases due to the elimination of errors. Good 5S practices are often successfully used in small and medium-sized enterprises, as presented in the study [40]. They enable the improvement of the company's efficiency, effectiveness and productivity [41], and also reduce the costs associated with the use of warehouse space as a result of limiting the amount of excess inventory produced. An inherent element of the 5S technique is the human factor [42]. For the use of this method to bring tangible benefits, every employee should be involved in its implementation. At this point, it is worth paying

attention to the weaknesses of the 5S method, which is the need to involve all employees, the time-consuming implementation and training of staff, and the constant need to develop and supervise the correct implementation of all stages of the concept.

The second analyzed method is value stream mapping, which is one of the main lean tools and involves a graphical presentation of all processes taking place in the company. Value stream mapping consists of several stages, starting from illustrating the state of the current process, through creating a vision of the future state, to developing an improvement plan. The first step is to collect all the necessary data regarding information and material flows and create a map. Each activity undertaken should be recorded on the map, even those that do not add value to the final result, i.e. are considered wasteful. After identifying areas of waste, a map of the future state should be created, containing proposals for improving flows. This is the starting base for creating the target improvement plan [43]. The VSM method is easy to perform and allows you to quickly identify where the problem occurs in order to eliminate it. Process improvement can reduce product flow time [44], save natural resources and minimize waste [45, 46]. It is also an opportunity to eliminate the problem of delays during the implementation of works on the construction site [47]. Due to the strong focus of the VSM concept on reducing waste, the use of this tool is an opportunity to achieve a Circular Economy [48]. In addition to numerous advantages, the mapping method also has its limitations. In order to achieve maximum results, it is necessary to perform it regularly. This results in continuous improvement of the value stream. Moreover, the first application of the VSM method only outlines the source of the problem, making it possible to completely eliminate the problem in subsequent applications. It is also important that all employees from every area of the company's operations are subordinated to the introduction of the lean philosophy. Despite its simplicity, the VSM method requires specialists with appropriate knowledge and experience in creating future state maps. Regular monitoring is particularly important due to the dependence on dynamic market changes, as well as supervision of the progress of activities. It is also necessary to establish a leader and create an effective system to motivate employees. Due to overly complicated processes in large enterprises, the implementation of this method may be very difficult or impossible due to the large amount of time required to carry it out.

4. Research methodology

Studies assessing the suitability of the 5S and VSM techniques were carried out using SWOT analysis, in accordance with the methodology described in the works [49, 50]. In order to obtain factors for the SWOT matrix, a detailed review of publications from recent years was carried out. The method of their selection was focused on the aspect of reducing waste, with particular emphasis on the issue of construction waste in the context of 5S and VSM methods. The obtained factors were assigned criteria meanings, then categorized (strengths, weaknesses, opportunities and threats) and assessed using a rating scale from 1 to 3, where 1 means low level, 2 – medium level, 3 – high level of a given feature. Each category was assigned 3 key features, in accordance with the author's assumptions. The sum of the weights assigned in each category was 1, and on this basis, weighted values were calculated and then summed. The last stage was to perform appropriate mathematical operations and determine one of the

strategies that should be adopted in the construction company. Four types of strategies have been distinguished:

- aggressive (maxi-maxi) – strengths and opportunities prevail,
- conservative (maxi-mini) – strengths and threats predominate,
- competitive (mini-maxi) – weaknesses and opportunities prevail,
- defensive (mini-mini) – weaknesses and threats predominate.

5. Research results and discussion

The research focused on a detailed analysis of two key lean management tools: the 5S method and value stream mapping (VSM). In both cases, both quantitative and qualitative criteria were used to assess their impact on processes in the construction industry, with particular emphasis on effective waste management. The evaluation of the 5S method is based on various criteria, such as simplicity of implementation, costs, ability to reduce waste and impact on workplace ergonomics. These criteria were weighted based on their qualitative and quantitative perception, which allowed for an objective presentation and assessment of the impact of the 5S method on work organization and operational efficiency in the context of waste management in the construction industry. Then, the detailed results were compiled and presented in Table 2 and Table 3. This summary presents individual ratings for each criterion, but also shows summed weighted values that reflect the overall effectiveness of the 5S method in the surveyed construction companies. This structured presentation of data allows for a better understanding of how specific aspects of the 5S method contribute to improving waste management and increasing operational efficiency. Analyzing the data presented in the tables, it was shown how important each of these criteria is in the context of the study and how their interconnections and importance affect the final assessment of the 5S method in the surveyed enterprises. This approach not only allows for an in-depth understanding of the data, but also highlights its usefulness in the real conditions of the construction industry, pointing to the opportunities and challenges related to the implementation of lean tools in this specific sphere of activity.

Table 2. The summary of categorized data regarding the 5S method along with an assessment

Strengths				**Weaknesses**			
Criterion	**Rating**	**Weight**	**Weighted value**	**Criterion**	**Rating**	**Weight**	**Weighted value**
Simplicity and low cost of use	2	0.45	0.9	The need to involve all employees	3	0.2	0.6
Reduction of waste	2	0.35	0.7	Time-consuming implementation of rules into the company's structure	2	0.45	0.9
Possibility to create an ergonomic workplace	3	0.2	0.6	The need to conduct employee training	1	0.35	0.35
Sum		**1**	**2.2**	**Sum**		**1**	**1.85**

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Opportunities				**Threats**			
Criterion	**Rating**	**Weight**	**Weighted value**	**Criterion**	**Rating**	**Weight**	**Weighted value**
Environmental protection by e.g. reducing the amount of waste, CO_2 emissions, reducing the consumption of raw materials	3	0.35	1.05	Limitation of implementation in micro-enterprises	1	0.15	0.15
Lowering the accident rate	2	0.4	0.8	The need for continuous improvement	3	0.4	1.2
Supporting waste segregation	3	0.25	0.75	The need to introduce specialist supervision (supervisor)	2	0.45	0.9
Sum		**1**	**2.6**	**Sum**		**1**	**2.25**

Table 3. The summary of categorized data regarding the VSM method along with an assessment

Strengths				**Weaknesses**			
Criterion	**Rating**	**Weight**	**Weighted value**	**Criterion**	**Rating**	**Weight**	**Weighted value**
Ease and speed of performing a thorough analysis	2	0.4	0.8	The need for teamwork	3	0.3	0.9
Accurate identification of sources of waste	3	0.45	1.35	Dependence of the future state map on variable factors due to dynamic market changes	2	0.4	0.8
Possibility to identify the impact of selected factors on the level of security in the enterprise	1	0.15	0.15	Difficulties in implementation in large enterprises	1	0.3	0.3
Sum		**1**	**2.3**	**Sum**		**1**	**2.0**

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Strengths				**Weaknesses**			
Criterion	**Rating**	**Weight**	**Weighted value**	**Criterion**	**Rating**	**Weight**	**Weighted value**
Opportunities				**Threats**			
Criterion	**Rating**	**Weight**	**Weighted value**	**Criterion**	**Rating**	**Weight**	**Weighted value**
Reduction of costs and working time	3	0.4	1.2	The need for periodic inspections and analysis of work progress	3	0.4	1.2
Reducing waste generated, saving natural resources	3	0.3	0.9	The need to employ a supervising specialist	2	0.3	0.6
Increased quality and efficiency of the company	3	0.3	0.9	Necessity to introduce an attractive motivational system	3	0.3	0.9
Sum		**1**	**3.0**	**Sum**		**1**	**2.7**

The SWOT analysis made it possible to determine the strengths and weaknesses, opportunities and threats of the usefulness of the two analyzed tools in construction waste management.

Analysis of the 5S method showed:

- **Strengths**: The 5S method is distinguished primarily by its simplicity and low cost of use, which was rated at 0.9 on a scale of weighted values. Moreover, an important advantage is the possibility of creating an ergonomic workplace (0.6) and reducing waste (0.7), which translates into improved operational efficiency of the company.
- **Weaknesses**: The biggest challenges related to the 5S method are the time-consuming nature of implementing the principles into the enterprise structure (0.9) and the need to conduct employee training (0.35), which may generate initial costs and require the involvement of all employees.
- **Opportunities**: In the context of opportunities, the 5S method promotes environmental protection by reducing the amount of waste and CO_2 emissions (1.05) and supports waste segregation (0.75). Additionally, the method can contribute to reducing the accident rate (0.8), which is particularly valuable in the construction industry.
- **Threats**: The main threats are the need for continuous improvement (1.2) and the need to introduce specialist supervision (0.9), which may generate additional operating costs, especially in micro-enterprises, where these costs may be particularly noticeable (0.15).

Analysis of the VSM method showed:

- **Strengths**: VSM effectively allows for accurate identification of sources of waste (1.35), which is crucial for process optimization. The ease and speed of carrying out the analysis (0.8) and the ability to identify the impact of selected factors on the level of security (0.15) additionally increase the value of this method.
- **Weaknesses**: The method requires teamwork (0.9), which may be difficult in large enterprises with a dispersed structure (0.3). Moreover, the dependence of the future state map on dynamic market changes (0.8) requires flexibility in the approach to planning and adaptation.
- **Opportunities**: VSM offers significant opportunities to reduce costs and working time (1.2), reduce waste generated (0.9) and increase the quality and efficiency of the company (0.9). These aspects are particularly valuable in the context of increasing competitiveness and sustainable development.
- **Threats**: The main threats are the need for periodic inspections and analysis of work progress (1.2) and the need to employ a supervising specialist (0.6), which may increase operating costs.

As shown by the SWOT analysis, in the case of both tools the categories "strengths" and "opportunities" dominate. For the 5S method, the advantages of its use in the construction industry (2.2) outweigh the disadvantages (1.85), and its implementation results in greater benefits for the company (2.6) than threats (2.25). Also in the VSM method, strengths (2.3) dominate over weaknesses (2.0) and possible opportunities (3.0) dominate over possible threats (2.7). It is worth noting that the obtained weighted values do not show significant differences between the lowest and the highest values: for the 5S method – 0.35, and for the VSM method – 0.3. The obtained results allow us to determine the necessary company strategy, which is presented in Figure 2 and Figure 3.

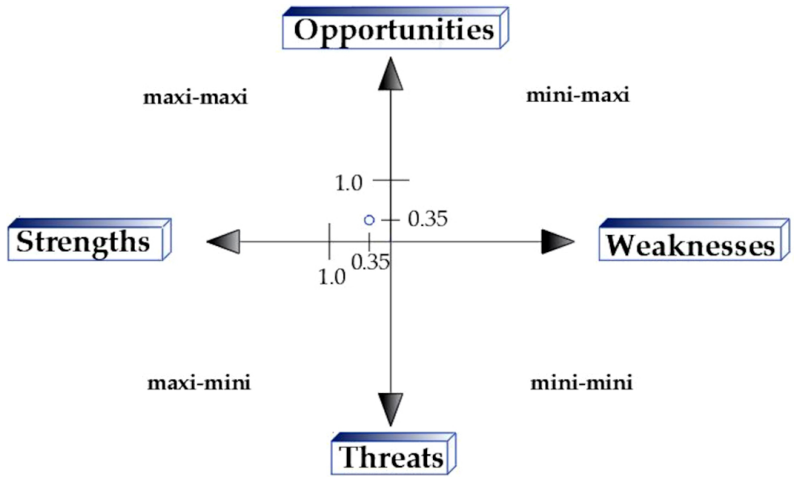

Fig. 2. SWOT analysis of the application of the 5S method in the construction sector

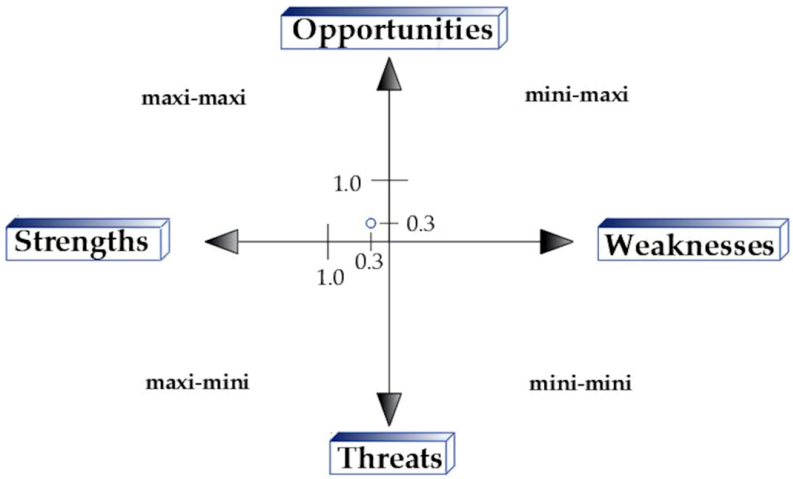

Fig. 3. SWOT analysis of the application of the VSM method in the construction sector

In order to achieve tangible benefits from the implementation of lean tools in the structures of construction companies, an aggressive strategy (maxi-maxi) should be chosen, which will enable maximum use of the advantages of each of the analyzed methods, as well as strengthen the correlation between the "strengths – opportunities" categories. Based on the research and literature review, it was found that the use of lean tools in the construction sector not only increases the efficiency and quality of operation of the entire enterprise, but above all fits into the idea of sustainable development. Implementing lean principles means simultaneously taking actions to protect the environment and supports the transition to a Circular Economy through the concept of eliminating all waste.

A similar SWOT analysis was carried out in the context of another lean method, the Kaizen method. The study [51] assessed the usefulness of the Kaizen method in the organizational structures of enterprises in the construction industry. Comparing the obtained results, it can be concluded that in order to achieve measurable benefits in the analyzed case, it is recommended that the company adopt an aggressive strategy. There was also a growing interest in the discussed method in European Union countries, especially in Poland, where the second highest publication rate on Kaizen was recorded, equal to 13.9%.

The tools discussed in this article were also the subject of other analyses, which can serve as examples of the usefulness of lean methods not only in the construction industry, but also in other sectors of the economy. In [47], the authors conducted research on the use of the VSM method in the process of designing a building. The case study included the construction of a prefabricated wooden house. The research results indicated the possibility of adapting the value stream map to the customer's needs, which constitutes an added value for the construction company. Another case describes the use of the VSM method to eliminate project implementation time losses and activities that do not generate added value at each stage of the construction of underground pipelines [52]. The results indicate the possibility of shortening the implementation time by 30.7% and reducing costs by 20.8% compared to the current state.

In [53], research on the use of the VSM method in the construction industry was carried out based on a literature review. As a result of the analysis, the authors divided the area of application of the VSM technique into three groups: the construction process stage, the macro-process and the construction support process. At each of these stages, a certain type of waste could be identified and the VSM was adjusted to eliminate it. Based on the research conducted, the authors conclude that VSM has great potential for use in construction, but in order for entrepreneurs to achieve the intended effects, certain changes must be made to the concept of this method due to differences in the realities of the production industry and the conditions of the construction sector.

6. Application examples

The implementation of lean management tools in the construction sector is becoming more and more common, but the level of advancement of such activities around the world is quite diverse. This results, among others, from different technological and financial capabilities of countries, the level of economic development and the legal aspect. However, there are examples of the use of these lean tools in practice.

The first example is the implementation of 5S principles at workplaces in a manufacturing company, where the problem of poor workplace organization was identified. The chaos at the workplace made it difficult to perform work due to wasted time looking for appropriate equipment and tools, as well as the necessary documentation. These devices were often damaged, which generated additional costs related to the need to purchase new ones. In [54], the authors analyzed the way employees use a milling tool cabinet, dividing it into several stages. The first stage was to observe the operators' work and identify existing problems. After proposing the possibility of solving them and accepting the management, the next stage began the implementation of the 5S method by, for example, appropriate marking of documentation, production of new tool racks and removal of empty packaging constituting waste. As a result of the changes introduced, the company achieved benefits in the form of a properly organized workplace, shortened working time, minimization of accumulated waste, and reduced costs related to the purchase of new equipment. The audit showed that the implemented changes were effective at 70%.

The VSM method was used for a comparative analysis of the total costs of constructing low-rise buildings using the 3DCP printing technique on-site and off-site [55]. For this purpose, appropriate mathematical models have been developed, taking into account aspects such as transport, storage, installation, printing, assembly and environmental issues. The case study was a 3D printed residential building in Beckum, Germany. The VSM method made it possible to determine the added value of all activities of the manufacturing process, from the supply of materials to the final implementation of the facility and the identification of areas of waste. One of such areas is the generation of waste, mainly at the stage of construction. Removing them may shorten the project duration and reduce implementation costs. Moreover, the elimination of waste adds value in terms of environmental protection. The comparative analysis carried out using the VSM method is a good tool enabling the selection of the most optimal concept

for the implementation of the facility in economic terms. The research presented in the study also has certain limitations related to factors such as: machine failure time, equipment life and opportunity costs.

7. Summary

The research shows that the use of 5S and VSM methods in construction companies affects the natural environment and the effectiveness of waste management, which is consistent with the principles of sustainable development. The implementation of these tools can lead to saving natural resources and reducing CO_2 emissions, which is of key importance in the ecological context.

Moreover, these methods contribute not only to reducing waste, but also to improving overall productivity by optimizing work processes. Reduction of waste and better work organization translate into lower operating costs. The introduction of the 5S and VSM methods can significantly improve the safety and ergonomics of workplaces, which translates into a lower accident rate and better quality of services and products. In the context of the research results, it is recommended for construction companies to adopt an aggressive strategy (maxi-maxi), which allows them to use the strengths and opportunities resulting from the implementation of 5S and VSM tools. This makes it possible to maximize the potential of these methods, leading to significant operational and strategic benefits. Despite numerous benefits, a significant barrier in the implementation of these tools is the lack of appropriate knowledge resources and technological limitations, especially in small and medium-sized enterprises. For this reason, it is crucial to invest in training and development of employee competences, as well as in the modernization of technical infrastructure.

Literature analysis showed a growing interest in lean in construction over the years 2013–2024, which confirms the growing popularity and usefulness of these methods in the construction sector. These conclusions indicate the need for further research focused on increasing the availability and affordability of technology and knowledge, especially in the context of small and medium-sized enterprises, detailed studies of the impact of 5S and VSM implementation on individual segments of the construction industry, and the development of methods for adapting and personalizing lean tools to better suit them. for the specific needs of various construction projects.

To sum up, the implementation of lean tools such as 5S and VSM in the construction sector offers significant benefits, but at the same time requires an appropriate strategic approach, investment in education and technology, and further research and adaptation of these methods.

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Zastosowanie analizy SWOT w gospodarce odpadami budowlanymi – przydatność metod 5S i VSM

Słowa kluczowe: analiza SWOT, dobre praktyki 5S, lean management, mapowanie strumienia wartości, odpady budowlane, sektor budowlany

Streszczenie:

W ostatnim czasie coraz większą uwagę zwraca się na sposób zarządzania i organizację pracy i produkcji w przedsiębiorstwach różnorodnych branż. Duży nacisk kładzie się na ograniczenie marnotrawstwa surowców, poprawę produktywności, a także minimalizowanie ogromnych ilości generowanych odpadów, co wpisuje się w koncepcję zrównoważonego rozwoju. Takie założenia są znane pod nazwą lean management (LM). Są to metody zarządzania z sektora produkcyjnego, których głównym celem jest eliminacja wszelkiego marnotrawstwa w każdym obszarze działania przedsiębiorstwa przy jednoczesnym podniesieniu poziomu jakości produktu końcowego. W ramach koncepcji LM funkcjonują różnego rodzaju narzędzia m.in. Kaizen, Just-in-Time, Poka Yoke, metoda 5S oraz VSM, które mogą być także z powodzeniem wykorzystywane w innych sektorach gospodarki, np. branży budowlanej. W tym kontekście koncepcja lean jest znana pod nazwą lean construction (LC). Koncepcja ta stanowi istotny element

procesu budowlanego, w celu szybszego, lepszego i tańszego wykonania zamierzonego zadania przy janaliza SWOT, dobre praktyki 5S, lean management, mapowanie strumienia wartości, odpady budowlane, sektor budowlanyednoczesnym minimalizowaniu ilości wytwarzanych odpadów, wykorzystywanych zasobów naturalnych oraz emisji CO_2, co wpisuje się w zakres działań na rzecz zrównoważonego rozwoju. Analiza literatury wykazała rosnące zainteresowanie lean w budownictwie w latach 2013–2024, co potwierdza rosnącą popularność i przydatność tych metod w sektorze budowlanym. Wnioski te wskazują na potrzebę dalszych badań skoncentrowanych na zwiększeniu dostępności i przystępności cenowej technologii i wiedzy, zwłaszcza w kontekście małych i średnich przedsiębiorstw, szczegółowych badań wpływu wdrożenia 5S i VSM na poszczególne segmenty branży budowlanej oraz opracowania metod adaptacji i personalizacji narzędzi lean, aby lepiej pasowały do specyficznych potrzeb różnych projektów budowlanych. Na podstawie analizy danych z bazy SCOPUS z lat 2013–2024 uzyskano liczbę publikacji znalezionych przy użyciu następujących słów kluczowych: „mapowanie strumienia wartości" – 327 publikacji, „narzędzie 5S" – 42 publikacje, „lean management" – 545 publikacji i „lean construction" – 298 publikacji. Zgodnie z uzyskanymi wynikami, w polskich publikacjach z lat 2013–2024 ponad 62% badań dotyczyło tematyki lean management, a jedynie 4,5% metody 5S. Warto zauważyć, że polscy autorzy publikują na temat mapowania strumienia wartości – 24,2% i koncepcji lean construction – 9,1%. Budownictwo jest jednym z najlepiej rozwijających się sektorów gospodarki w ostatnich latach. Jednak z uwagi na silną zależność od czynników ekonomicznych, społecznych oraz prawnych, a także indywidualność realizowanych projektów, sektor ten często jest narażony na różnego rodzaju problemy, m. in. niewystarczające środki finansowe, nieterminowa realizacja założonych przedsięwzięć, produkcja ogromnych ilości odpadów, problem w utrzymaniu wysokiego poziomu jakości produktów i usług. Rokrocznie sektor budowlany produkuje 30% globalnych odpadów, co stanowi duże wyzwanie w aspekcie recyklingu i utylizacji, szczególnie w krajach niedysponujących wystarczającymi środkami finansowymi i możliwościami technologicznymi. W celu rozwiązania zaistniałych problemów warto zastanowić się nad wdrożeniem zasad lean w struktury przedsiębiorstw budowlanych, co jest działaniem obecnie coraz częściej podejmowanym. Niestety, istnieją także pewne ograniczenia we wdrażaniu narzędzi lean w przedsiębiorstwach i są to głównie niewystarczające środki finansowe, luki w zapleczu kierowniczym oraz niewystarczająca wiedza. Mając zatem na względzie kwestie finansowe oraz poziom skomplikowania implementowanych metod, często wybieranymi narzędziami lean jest technika 5S oraz narzędzia z obszaru zarządzania wizualnego, np. mapowanie strumienia wartości (VSM), które to metody zostały przedmiotem niniejszych badań. Metoda 5S jest skutecznym narzędziem w celu lepszej organizacji miejsca pracy. Pozwala stworzyć optymalne warunki przy niskich nakładach finansowych. Polega na m.in. stałym sortowaniu narzędzi na miejscu pracy przy jednoczesnej segregacji powstałych odpadów. Dlatego też wdrożenie zasad 5S stanowi istotne narzędzie w celu ograniczenia ilości generowanych odpadów budowlanych oraz może usprawnić działania związane z obowiązkowym w świetle przepisów prawnych, segregowaniem przez firmy powstałych odpadów według ich rodzaju. Drugą z analizowanych metod jest VSM, stanowiąca jedno z głównych narzędzi lean, polegające na graficznym przedstawieniu wszystkich procesów zachodzących w przedsiębiorstwie. Metoda ta jest łatwa w przeprowadzeniu i ozwala w szybki sposób zidentyfikować miejsce występowania problemu w celu jego eliminacji. Ze względu na silne ukierunkowanie techniki VSM na ograniczanie marnotrawstwa, zastosowanie tej metody jest szansą na osiągnięcie Gospodarki o Obiegu Zamkniętym. W niniejszym opracowaniu zidentyfikowano dwa najchętniej wybierane narzędzia lean, mogące przyczynić się do ograniczenia ilości generowanych odpadów. Analizie SWOT poddano metodę 5S oraz metodę VSM, celem określenia ich przydatności w sektorze budowlanym. Wyniki analizy uwidaczniają dominację kategorii "mocne strony" i "szanse" dla obu badanych narzędzi. Uzyskane wartości ważone w obu przypadkach nie wykazują wzajemnie dużych różnic, a między najniższą a najwyższą wartością wynosi ona: dla metody 5S – 0.35, a dla metody VSM – 0.3. W związku z tym, aby osiągnąć wymierne korzyści

z wdrożenia narzędzi lean w struktury przedsiębiorstw budowlanych, należy obrać strategię agresywną (maxi-maxi), która pozwoli na maksymalne wykorzystanie zalet każdej z analizowanych metod oraz wzmocni zależność między kategoriami "mocne strony – szanse". Ponadto, w opracowaniu dokonano także przeglądu literaturowego opracowań z lat 2013–2024 opublikowanych w państwach członkowskich Unii Europejskiej, podstawą którego była baza SCOPUS. Wyniki uzyskano na podstawie wpisywania określonych słów kluczowych takich jak: „value stream mapping", „5S tool", „lean management" oraz „lean construction". Jak wynika z danych, najwięcej publikacji z założonego przedziału czasowego dotyczyło zagadnień związanych z tematyką "lean management" (545 publikacji), a najmniej z obszaru metody 5S (42 publikacje). Pomimo faktu, iż w polskich opracowaniach często jest podejmowana tematyka dotycząca koncepcji lean management (62.1%), to jej implementacja w sektorze budowlanym jest dosyć początkującym trendem (9.1%). Podsumowując, przeprowadzone badania wykazały, że w celu uzyskania jak największych korzyści z zastosowania narzędzi 5S i VSM, najbardziej korzystna do przyjęcia w przedsiębiorstwie budowlanym będzie strategia agresywna. Wdrażanie metod 5S oraz VSM pozwala na ograniczenie ilości generowanych odpadów budowlanych, oszczędność zasobów naturalnych, ograniczenie zanieczyszczenia powietrza oraz emisji CO_2. Z uwagi na wymierne korzyści jakie przynosi zastosowanie koncepcji lean w branży produkcyjnej, przedsiębiorcy budowlani powinni skupić się na poszerzeniu wiedzy w tym zakresie oraz stwarzać możliwości zastosowania wybranych technik w swoich firmach. Sukces jaki odniosło wdrożenie metod lean w struktury przedsiębiorstw innych branż, powinien być motywacją do działania na rzecz rozwoju przedsiębiorstw oraz przejścia na Gospodarkę o Obiegu Zamkniętym. Tematyka wdrażania narzędzi lean w branży budowlanej jest bardzo istotnym zagadnieniem i wymaga przeprowadzenia dalszych badań.

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