Logistics, supply chain, sustainability and global challenges
Vol. 13, iss. 1, December 2022, 19-31
doi: 10.2478/jlst-2023-0002

Appropriate criteria for a transition from conventional to sustainable warehousing

*Anita VASILEVA[1], Ana M. LAZAREVSKA[1] and Kristina JAKIMOVSKA[1]

[1] Ss. Cyril and Methodius University in Skopje,
Faculty of Mechanical Engineering-Skopje, R. Macedonia

[Corresponding Author indicated by an asterisk *]

***Abstract* — This research paper conducts the process of selecting the criteria that are the most appropriate for a transition from conventional to sustainable warehousing. SWOT analysis is used to emphasise the weaknesses of conventional and the strengths of sustainable warehousing to select the most appropriate for the herein presented study. The results have been verified via a questionnaire filled out by professionals in economics, logistics and warehousing, and mechanical engineering. be added under the methodology section. The results gave the five most important criteria by transforming the conventional into sustainable warehousing. Finally, the paper concluded that renewable energy sources are the most important criteria for transforming by conventional to sustainable warehousing by environmental aspects, as well as the smart technology is above all other criteria by economic aspect. Moreover, providing personal protection equipment and servicing machinery and vehicle on regular basis are the two mainly criteria by social (safety) aspect.**

***Index Terms* — logistics, sustainable warehousing, SWOT analysis, renewable energy**

I. INTRODUCTION

The need for research is supported by a review of previous surveys in the field of weaknesses in conventional warehousing, and the need for environmentally friendly, safe, and economical warehousing. First, in Lewczuk (2021) a warehouse is defined as an assumption of responsibility for the storage of goods, raw materials, work in process, and spare parts. A warehouse consists of a storage area, input and output buffer areas, and an internal transport area, that in cooperation makes the warehouse process consisting of receiving, putting away, storage, retrieval, and shipment. Furthermore, according to Mumba (2020) the main activities and responsibilities of having the warehouse is maintaining the appropriate items, manage new stock coming, packing, and shipping orders, tracking and improving overall storage, as well as arranging for dispatching finished goods to end users. Kamali (2019) points out that the warehouse is installed in a way to work with a space in which certain factors limit the available surface area, and to cover all requirements for day to day activities in the warehouse. Warehousing, as a concept, is the act of organizing, controlling, and ensuring all warehousing activities in the most optimal way possible.

According to Kamali (2019), conventional warehousing primarily harnesses a manual handling system; therefore, they have a lower reliance on technology. In Kadam, Karvekar & Kumbhar (2017) conventional warehousing has outdated machinery, and no energy conservation, space optimisation, or internal transportation. However, as stated in reference, the fear of change, adjustments, large initial investments, and other factors contribute to the significant presence of conventional warehousing.

On the other hand, Kuhlman & Farrington (2010) defined sustainability as “the principle of ensuring that our actions today do not limit the range of economic, social and environmental options open to future generations”. Amjed & Harrison (2013) represents a theoretical model for sustainable warehousing. The author’s content analysis is to identify and develop sustainable warehousing themes that are rigorously tested against industry standards to ensure their validity and reliability. Hence, Mulder (2013) presented a multi-criteria analysis as a list of more than 20 recommended options, like dynamic lighting with motion sensors, a wind turbine, PV panels, etc. In Malinowska, Rzeczycki & Sowa (2018) the authors indicate directions and changes in technological, managerial, social, environmental, and economic aspects of warehouse functioning that are required to go forward towards a sustainable tendency.

Bartolini, Bottani & Grosse (2019) shows an increasing interest in sustainability, where energy saving has been the primary goal, followed by environmental impact of warehousing buildings and green warehouse management. Żuchowski (2015) concludes that a green warehouse will eventually result from sustainable warehouse management practices because they reduce resource consumption and greenhouse gas emissions. In such a way Đukić, Česnik &

Opetuk (2010) presents an overview of order-picking methods and technologies of green supply chain management in way to reduce energy consumption and impact the greening of warehousing.

Thus, Accorsi, Bortolini, Gamberi, Manzini & Pilati (2017) defined the general building dimensions in order to optimise storage capacity and handling performances. According to Burinstkiene, Lorenc, & Lerher (2018) a standard for creating sustainable inner-warehouse operations is made. The majority of them suggest revision of assignment and schedule of warehouse's gates to suppliers, incorporating the plan for product arrival in the warehouse, using combined routes, and multi-picking implementation. Also, Freis, Vohlidka, & Günthner (2016) provides insight of the energy interactions within the system logistics centre for decision-making during the planning of energy-efficient and CO2-neutral systems. For example, forklifts that double as servers and assess the effectiveness of energy control policies are some of the extended energy efficiency techniques for warehousing suggested in Anand, Lee & Prabhu (2014). According to Wahyuni, Najah & Santoso (2022) it is intended to design sustainable warehouse procedures in the Agro-hub Banten. Richnák & Gubová (2021) therefore presents a survey on the use of reverse and green logistics in the context of sustainable development in companies in Slovakia. Storgärd (2021) lists several factors that can improve a warehouse's energy efficiency which are of greater importance to reduce the environmental impact of warehouse operations. Carli, Digiesi, Dotoli & Facchini (2020) offers a management strategy that takes into account the presumption that available equipment will enable a rise in warehouse productivity at negligible costs. With this purpose, an optimization model is proposed in order to determine an optimal control strategy for the battery charging of a fleet of electric mobile MHE, allowing for the reduction of the financial and environmental impact of material handling activities in labor-intensive warehouses. In Füchtenhans, Glock, Grosse & Zanoni (2021) a simulation model with three different operating strategies for lighting systems is accomplished and compared to a conventional lighting system. These operating strategies define various types of smart lighting technologies. Wahab, Shakrein Safian, Othman & Mohamad Azhar (2021) identified seven factors that should motivate a company to adopt sustainable warehouse management in order to improve its competitive advantage.

According to Iancu & Moga (2022) the best approaches for structural solutions and component selection are recognised as the best methods for industrial building verification and sustainability. Additionally, Modica, Perotti & Melacini (2021) demonstrates an input-process-output model that connects organisational variables and LIB (the lithium-ion battery) forklift-related costs with an application to real-world situations. The findings by Agyabeng-Mensah, Ahenkorah, Afum, Dacosta & Tian (2020) indicate that supply chain sustainability serves as a competitive mediator between both logistics optimisation and green warehousing and economic performance. In order to improve economic performance, the paper advises businesses to adopt sustainable practices that have an impact on both the social and environmental bearing. Ali & Phan (2021) aimed to review the literature on the subject of how Industry 4.0 and sustainable warehousing interact.

Ries, Grosse & Fichtinger (2017) presents the possibility to purchase green energy, in particular reducing the amount of electricity produced from a coal could further reduce the carbon footmark of a warehouse and facilitate environmental sustainability. On the basis of the comparative analysis of feedstock recycling and energy recovery, Pongrácz (2007) suggests another form of packaging reuse - the refill packages, which are more advantageous from an economic and environmental standpoint. Additionally, lighter packaging and more concentrated products contribute to better resource usage. In Petersen (2022) is presented an article about sustainable warehousing that makes use of recyclable packaging. According to Gülmez & Rad (2017) only effective sustainability strategies can lessen the negative effects that the sector has got on the environment. In this context, companies must promote reverse-logistics programs, choose environmentally-friendly technologies for vehicles, rearrange shipping plans and routes, routinely check their vehicles' emissions, and stop using aged vehicles. Furthermore, Gibberd (2021) provides helpful information that can be used to comprehend how environmental impacts in buildings can be decreased through the selection, design, and integration of green building technologies. In Saroha (2014), the impact of green logistics is discussed in more detail. In Grzybowska, Awasthi & Sawhney (2020) information on current sustainability knowledge, upcoming research and relevant practices from the industry is presented. Moreover, Buntak, Kovačić & Mutavdžija (2019) illustrated that it is suitable for the development and implementation of the IoT technologies to be in the focus of today's logistics industry and the development of warehouse systems. In this regard, Lewczuk & Kłodawski (2020) presented the issue of logistics information and systems processing it in logistics chains in a basic manner. Jayarathna, Agdas, & Dawes (2022) discusses the application of the concept of "green" logistics and "green" technologies in transport in the transportation process. Both customers and states are taken into account when it comes to environmental safety during the transportation process.

Last but not least, the support decision tool described in Boenzi, Digiesi, Facchini, Mossa & Mummolo (2016) enables users to identify the overall impact of all energy-consuming aspects of warehousing activities and guides them in selecting the best logistical solutions to minimise the environmental impact of material handling activities.

Logistics, supply chain, sustainability and global challenges
Vol. 13, iss. 1, December 2022, 19-31
doi: 10.2478/jlst-2023-0002

The literature review findings indicate that there are no well-defined strategies for making the transition from conventional to sustainable warehousing. To fill the current "gap" in the field, this research conducts both a literature review and applied research. Green warehousing and smart warehousing are two lenses through which sustainable warehousing is examined in this research paper. Hence, the main goal of this research paper is to find concepts that would be most useful for the transition from conventional to sustainable warehousing.

II. METHODOLOGY

The approach taken in this paper is qualitative and quantitative. Secondary data information for problem identification and problem statement is also used. Fig. 1 illustrates the steps taken to elaborate on the problem – the transition from conventional to sustainable warehousing.

A systematic review was used to recognise the weaknesses of the conventional warehousing.

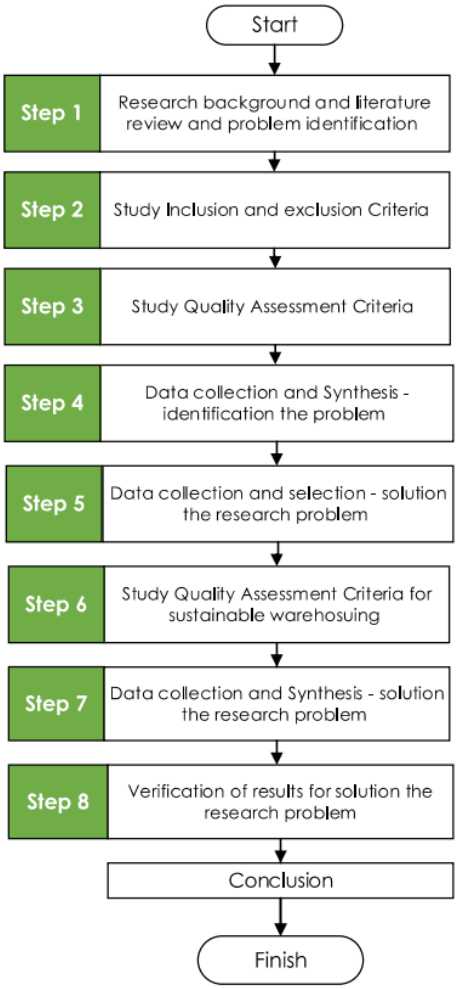

Fig.1. Research methodology flowchart

A. Research background, literature review and problem identification (Step 1)

This paper is based on data that is extracted mainly from academic literature and publications (Scopus, Web of Science, IEEE Xplore and ScienceDirect) through attentive content analysis. Firstly, the search terms are just simple keyword combinations. The keywords used in the search are: conventional warehousing, warehousing weaknesses (Fig.1, Step 1). The literature analysis reveals that conventional warehousing is a subject of numerous studies.

B. Study Inclusion and exclusion Criteria (Step 2)

The inclusion and exclusion criteria serve as a source to examine the significance of the data. This step includes all systematic reviews watched over in the domain of conventional warehousing. The criteria are:

- Inclusion Criteria:

- the systematic literature review only;
- the systematic literature reviews conducted in English language only;
- systematic literature reviews about conventional warehousing.

- Exclusion Criteria:
  - the studies other than conventional warehousing;
  - the duplicate studies;
  - the studies published in a language other than English.

C. Study Quality Assessment Criteria (step 3)

The quality assessment criteria (QAC) explain the findings and offer better chances to summarise the research Yang et al. (2021).In this paper a check-list is created, in order to evaluate the quality of the studies, which is based on same preliminary research questions. The check-list is assembled of simple questions which are related to the conventional warehousing. These questions are meant to investigate the most reliable studies for conventional warehousing. In QAC, the studies are given points in order to determine whether or not a certain study is close to the research domain. A research study receives 1 point if it completely responds to a question; otherwise, it receives a score of 0. The research study receives 0.5 points for each partial expectation of the answer (Table I).

Table I. The quality assessment criteria of conventional warehousing

	Quality assessment criteria	Answers and points
1.	Does the research study discuss conventional warehousing?	Yes=1; Partially=0.5 No=0
2.	Is the study a systematic literature review?	Yes=1; Partially=0.5 No=0
3.	Is the study about characteristics of conventional warehouse?	Yes=1; Partially=0.5 No=0

D. Data collection and Synthesis - identifying the problem (step 4)

This step of review protocol is focused on the selection of the research studies. The data collection depends on the suggested research question (Table I). Consequently, three studies are included in this section of the research. Mumba (2020) used the conventional warehousing as his foundation, outlining its advantages and disadvantages. The characteristics of traditional warehousing were identified by Kamali (2019). Finally, a redefinition of conventional supply chain management was shown in Kadam, Karvekar & Kumbhar (2017). To point out the weaknesses of conventional warehousing the SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis of conventional warehousing was created (Sammut-Bonnici & Galea, 2015). Table III presents a summary of the research studies along with focused weaknesses of the conventional warehousing.

E. Data collection and selection - solution the research problem (step 5)

Following that, a new literature review was conducted to identify solutions to strengthen the weaknesses summarised in Table IV. The literature review is once more based on data that is extracted from online sources, such as: Scopus, Web of Science, IEEE Xplore and ScienceDirect. Green warehousing and smart warehousing are the lenses through which sustainable warehousing are examined in this research paper (Fig.2). In light of this, the following key phrases are used:

- sustainable warehousing;
- green warehousing;
- smart warehousing;
- renewable sources in warehouses;
- Energy efficient warehousing.

In this step, each of systematic reviews conducted in the domain of sustainable warehousing are included. The criteria are:

- Inclusion Criteria:
  - the systematic literature review only;
  - the systematic literature reviews conducted in English language only;
  - systematic literature reviews about sustainable warehousing.
- Exclusion Criteria:
  - the studies other than sustainable warehousing;
  - the duplicate studies;
  - the studies published in the language other than English.

F. Study Quality Assessment Criteria for sustainable warehosuing (step 6)

Once more, a check-list is created in this section to determine the quality of the data collected in the field of the key words listed in step 5. The check-list consists of basic questions pertaining to sustainable warehousing (Table II). In this step, the points are distributed in the same way as they are in Table I.

Table II. The quality assessment criteria of sustainable warehousing

	Quality assessment criteria	Answers and points
1.	Does the research study discuss sustainable warehousing?	Yes=1; Partially=0.5 No=0
2.	Is the study a systematic literature review?	Yes=1; Partially=0.5 No=0
3.	Is the study about one of these topics: – green warehousing – smart warehousing – reverse logistics in warehouse – renewable sources in warehouses, – energy efficient warehousing?	Yes=1; Partially=0.5 No=0

G. Data collection and Synthesis – addressing the research problem (step 7)

The selection of the research studies is addressed in this review protocol step. The literature review collection follows Table II. Thus, Malinowska et al. (2018) proposed an application model for sustainable warehouse. Additionally, a roadmap for sustainable warehousing was used by Amjed & Harrison (2013). The model by Mulder (2013) provided the answer on how to build warehouse in sustainable and economical way. Bartolini et al. (2019) presented the systematic literature review and bibliometric analysis of green warehousing, and Đukić et al. (2010) illustrated the order-picking methods for greener warehousing. Moreover, Ries et al. (2017) presented the importance of packing for achieving a sustained development. The characteristics of the smart warehousing are used by Kamali (2019) and implementation of smart warehousing is presented by Buntak et al. (2019). After reviewing the literature, a combined SWOT analysis of sustainable warehousing was conducted. (Table IV).

H. Verification of results to address the research problem (step 8)

To verify the strength of the SWOT analysis for sustainable warehousing, the questions in the questionnaire were created based on Table III. The goal was to conduct the questionnaire with subject-matter experts (warehouse logistics expert, mechanical engineering (field: machine design, transport systems and logistics) and economic expert) and to get their feedback about the importance of sustainable warehousing factors (Table VI). Firstly, the questionnaire was posted to three experts for a pilot study. The aim was to elicit feedback on how the questionnaire should be improved and amended. Suggestions and recommendations for improvement from all three respondents were incorporated into the completed questionnaire before it was distributed to the sample. Finally, the questionnaire was sent to experts. The questionnaire was completed online, using Google Forms. The questionnaire was posted to fifteen experts, but the questionnaire resulted in a response rate of 60%, or 9 respondents. The responders were: 30%- warehouse logistics expert, 30% mechanical experts, and 40% economic experts. All respondents are more than 25 years old. Data was collected from August 2021 to June 2022 in Skopje. The

questionnaire was completed online, using Google Forms. Participants were given 17 questions to fill in the survey. The questions were considered by three aspects: Environmental, Economic, and Social (Safety). The Likert scale (Joshi, Kale, Chandel, & Pal, 2015) was used in the questionnaire that converted it into points (1- being the least important, 5- being the most important). To verify the results obtained in questionnaire, the general statistics equation (1) is used for min-max normalization (Ali & Faraj 2014). The basis of min-max normalization is rescaling the range of feature values to scale the range of [0, 1] or [-1, 1]. With the help of the normalization equation (1), a data set is modified so that all of its variations fall between zero and one. This helped in comparing two or more data sets with different scales.

$$X' = \frac{X - X_{min}}{X_{max} - X_{min}} \quad (1)$$

Where:

- the X is the data point;
- the X_{min}-minimum value in the group of responses (from the questionnaire);
- the X_{max}-maximum value in the group of recorded responses.

III. Results and Discussion

Based on the inputs from the literature review, SWOT analysis of conventional warehousing was conducted (Table I).

Table III. SWOT analysis (conventional warehousing)

Conventional warehousing	**S**trengths	
		▪ Low initial costs due to the use of conventional machinery, ▪ Less dependent on technology - conventional warehousing primarily harnesses a manual handling system
	Weaknesses	
		▪ Inefficient materials handling equipment - Involve using outdated and unreliable machinery, machinery with a higher failure rate and lower workplace safety ▪ The need for more workers and more time - many cubic areas are not being utilised to their full potential, resulting in increased internal transportation, and increased movement ▪ Do not practice any energy conservation - inefficient use of electric energy, all of which results in increased time and cost expenditure ▪ Over-handing materials - handling items in typical warehouses involves multiple unnecessary additional movements
	Opportunities	
		▪ Job creation - The constant need for manpower to perform tasks in the warehouse
	Threats	
		▪ New trends requirements - the new demands of customers, and the need to adapt to current technological policies aim at the adoption of the era of smart, automated, wireless controls.

(Source: aggregated by authors based on literature review)

According to Table III, the most frequent issues of the conventional warehousing are associated to the handling equipment, inefficient use of the warehouse areas and ineffective energy consumption. Furthermore, by gathering relevant data (Fig.2), it is clarified that using smart and green warehousing can mitigate the mapped weaknesses of conventional warehousing. According to the literature review, the union of these two practices (smart and green warehousing) is presented as sustainable warehousing (Fig.2). As a result, the SWOT analysis is arranged to ensure that sustainable warehousing is properly implemented (Table IV).

Logistics, supply chain, sustainability and global challenges
Vol. 13, iss. 1, December 2022, 19-31
doi: 10.2478/jlst-2023-0002

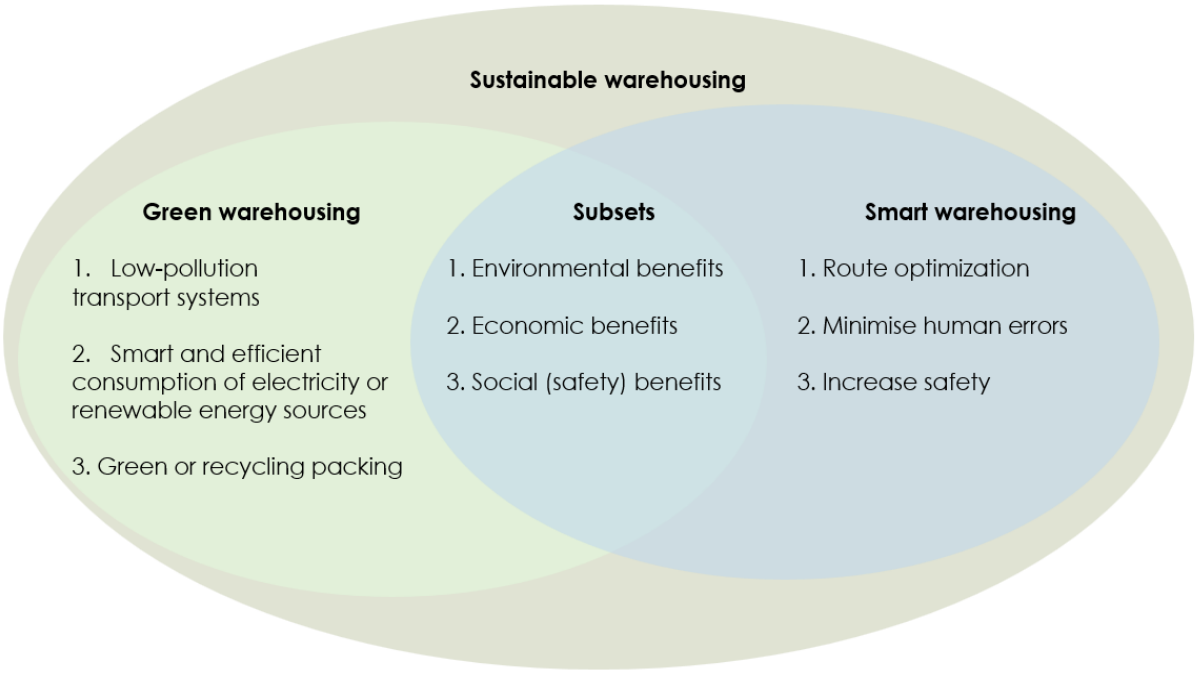

Fig.2. Subsets of sustainable warehousing

Table IV shows us that strengths of the conventional warehousing are a union of implementing smart warehousing and green warehousing. The literature has shown that shift work, especially night work results in sleep problems. This impacts the mental and physical health, immune system, safety, and productivity of the warehouse staff. Thus implementing smart warehousing means utilizing IoT as well as automated and autonomous handling machines. As a result, there is a reduction in the amount of human interference and error, balanced shifts are introduced to minimise the disruption of natural body clocks, order picking and handling efficiency is increased, and customers' needs can be accommodated more readily. Reduced order-picking time is another benefit of vehicle route optimisation.

On the other hand, green warehousing activities such as reverse logistics, renewable energy sources for running warehousing, maximise the use of natural sunlight; efficiently manage the artificial lighting in the warehouse; maintain temperature at a level that requires least amount of energy are minimised in all non-environmental segments. The subset of smart and green warehousing is resulted in a high standard for workplace health and safety. However, every warehousing implementation has its own advantages and disadvantages. The main weakness of sustainable warehousing is that the cost of building a sustainable warehousing is more expensive compared to the conventional warehousing. It is also not inexpensive to outfit a warehouse building with renewable energy sources. While the automation cost may be one-time, the operating costs are ongoing and require significant maintenance. Moreover, sustainable warehousing require new machinery, newly trained staff i.e., new skills and expertise, which are difficult to obtain.

Table IV. SWOT analysis of sustainable warehousing

Strengths
✓Perform all warehousing operations with as few errors as possible;
- Implementing smart warehousing can increase logistics system productivity through speed as it is an easy way of rapid data input (using IoT), accuracy, and reliability.
✓Flexibility and efficiency in response to customer requests;
- A smart warehousing allows more efficient order-picking and handling, allowing flexibility to customers' needs
✓Elimination of all unnecessary expenditures;
- Keeping an optimum level of inventory (or stock) results in improved revenues; increased warehouse utilisation Malinowska et al. (2018);
- Optimise the picking process to reduce the picker's travel time.
✓Minimisation of all non-environmental segments;
- Using green warehousing

Strengths
✓ High staff safety;
- Maintain high standards for workplace health and safety, as well as balanced shifts to minimise disruption of natural body clocks.
Weaknesses
✓ High initial and capital costs.
-The cost of building a sustainable warehousing
- Fitting a warehouse building with renewable energy sources.
✓ Newly trained staff;
- New machinery, newly trained staff i.e., new skills and expertise.
Opportunities
✓ Focusing on technology for future sustainable warehousing related R&D.
- Investing in sustainable warehousing to achieve bigger goals.
Threats
✓ Absence of concrete financial measures to support projects related to the development of sustainable warehousing.
✓ Requirement for loans for ongoing development.
✓ Pandemics that may disrupt the economic and social framework of the countries.

Source: aggregated by authors based on literature review

Additionally, based on the strengths and weaknesses presented in SWOT analysis, this paper has concluded that focusing and investing in technology for future sustainable warehousing creates opportunities for achieving more ambitious goals. Finance, specifically the lack of specific financial measures and the need for loans for ongoing development, was mentioned as one of the main threats identified in this paper. It is clear from looking back over the past two and a half years, that the pandemic has had a wide impact on the economic and social framework of the nations around the world.

Table V enlists the criteria deriving from the conducted SWOT analysis (Table IV), whereas Table VI indicates the importance of those criteria relevant for the transformation from conventional to sustainable warehousing. Table V shows that implementing smart and green warehousing as well as staff training are the two most crucial requirements that must be met in order to convert conventional warehousing into sustainable warehousing.

Table V. Sustainable warehousing criteria *(Source: elaborated by authors)*

Strengths	**Criteria**
Perform all warehousing operations with as few human errors as possible;	▪ Smart warehousing - Smart technology ▪ Staff training
Flexibility and efficiency in response to customer requests;	
Elimination of all unnecessary expenditures;	▪ Optimisation Malinowska et al. (2018) - Inventory optimisation - Route optimization

Reduction of all non-environmental segments;	▪ Green warehousing - Eco-friendly forklifts - Reverse logistics - Noise pollution reducing - Renewable energy sources - Clean energy o Product stocked, humidity, weather conditions, the orientation of the warehouse facility, type of solution used in walls o Choice of luminaries o Daylight usage
High staff safety;	▪ Safety - Restricting access to only authorised people, implementing specific rules for warehouse traffic - Providing personal protection equipment (PPE) - Staff training - Adopting employee-friendly shifts management practices

Table VI. The importance of criteria *(Source: the results given are from the survey)*

Criteria	Environmental aspect	Economic aspect	Social (safety) aspect
1. Smart warehousing			
1.1. Smart technology	0.2	1	4.33
2. Optimisation			
2.1. Inventory optimisation	0.61	0.78	0.39
2.2. Route optimisation	0.2	0.78	0.3
3. Green warehousing			
3.1. Eco-friendly forklifts	0.89	0.89	0.59
3.2. Reverse logistics	0.67	0.83	0.53
3.3. Noise pollution reducing	0.56	0.59	0.67
3.4. Renewable energy sources	1	0.89	0.44
3.5. Clean energy			
3.1.1. Product stocked, humidity, weather conditions, orientation of the warehouse facility, type of in solution used in walls	0.6	0.56	0.39

3.5.2. Choice of luminaries	0.5	0.61	0.4
3.5.3. Daylight usage	0.89	0.56	0.3
3.5.4. State-of-the-art roof design which can help to collect rainwater	0.4	0.61	0.3
4. Safety			
4.1. Restricting access to only authorised people, implementing specific rules for warehouse traffic	0.5	0.28	0.89
4.2. Providing personal protection equipment (PPE)	0.3	0.2	1
4.3. Staff training	0.56	0.67	0.83
4.4. Adopting employee friendly shifts management	0.63	0.18	0.78
4.5. Servicing machinery and vehicle on regular basis	0.78	0.61	1

The questionnaire was used to verify the importance of the criteria. Table 6 displays the results using the min-max normalization. In this study, the verification is made by three aspect: environmental, economic and social (safety).

For greater transparency, the results from Table 6 are presented in charts (Fig.6, Fig.7 and Fig.8). In that regard, (Fig. 6) illustrates the top five criteria by environmental aspect. As per the results, the most important criteria for transforming from conventional to sustainable warehousing are renewable energy sources. Fig. 7 presents the top five criteria by economic aspect. As demostrated, smart technology is above all other criteria by economic aspect.

Finally, the two main criteria for transforming the conventional warehousing into sustainable warehousing, by social (safety) aspect, are providing personal protection equipment (PPE) and maintaining machinery and vehicles on a regular basis (Fig. 8).

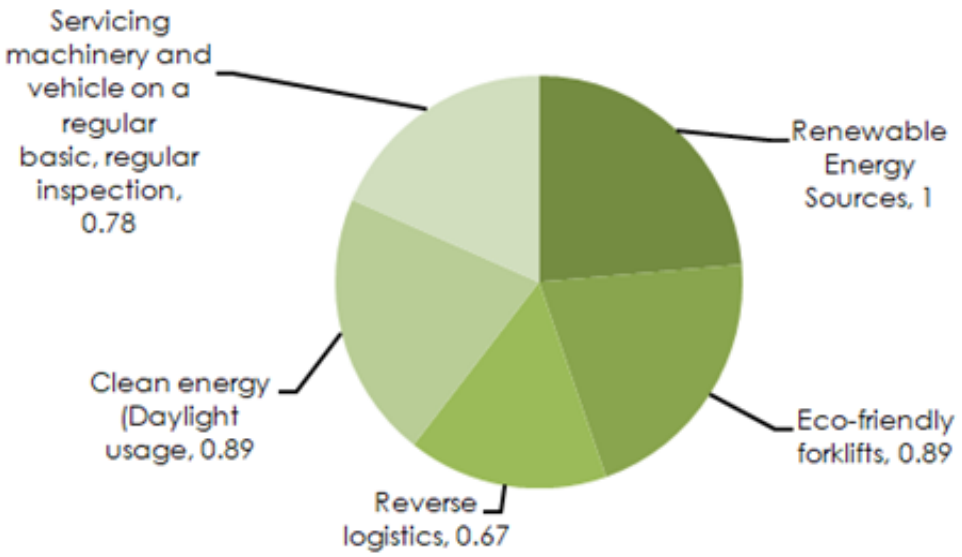

Fig. 6. The five most important criteria by environmental aspect

Logistics, supply chain, sustainability and global challenges
Vol. 13, iss. 1, December 2022, 19-31
doi: 10.2478/jlst-2023-0002

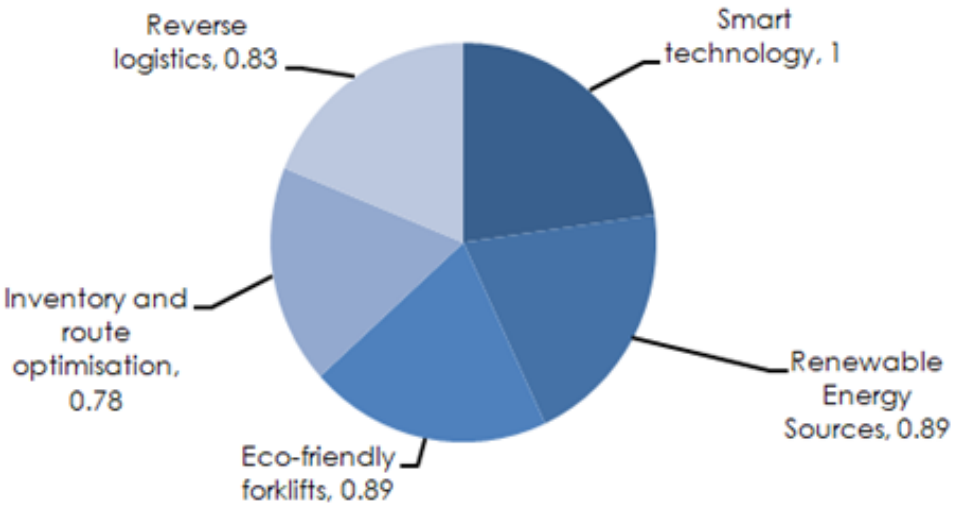

Fig. 7. The five most important criteria by economic aspect

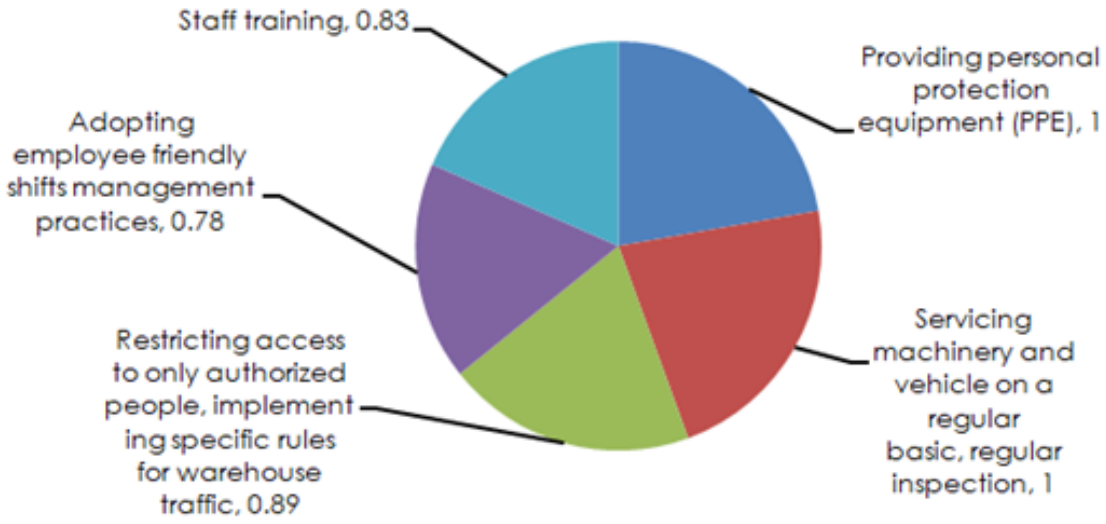

Fig. 8. The five most important criteria by social (safety) aspect

VI. CONCLUSION

The paper is helpful in identifying the weaknesses in traditional warehousing and addressing them through the three aspects of sustainability. The result of the SWOT analysis for sustainable warehousing proved the symbiotic relationship between the smart and green warehousing. The results of the conducted survey via a tailor-made questionnaire provides a division of the criteria based on their importance According to the results of the questionnaire, the three most important factors are: renewable energy source (by environmental aspect); smart technology (by economic aspect) and providing personal protection equipment (PPE), and servicing machinery and vehicles on a regular basis, as well as regular inspection by social (safety) aspect. The paper has both practical and academic value and it can be used as a guide for establishing future maintenance objectives for warehousing.

Additionally, experimental studies can be used to evaluate reliability. If these criteria prove to be appropriate and straightforward to implement, this approach can be proposed for wider use, with necessary alterations based on the warehouse's features. The complexity of the considered issues indicates the need for further investigation and deepening of the research. Further review to be considered are: detailed consideration of the methodological

approach by defining more precise criteria, as well as a complete analysis. It is crucial to incorporate more studies papers, as well as additional subject-matter experts, and experimental investigations implementation.

REFERENCES

Accorsi, R., Bortolini, M., Gamberi, M., Manzini, R. & Pilati, F. (2017). Multi-objective warehouse building design to optimize the cycle time, total cost, and carbon footprint. *The International Journal of Advanced Manufacturing Technology, 92, 839–854*. doi:10.1007/S00170-017-0157-9

Agyabeng-Mensah, Y., Ahenkorah, E., Afum, E., Dacosta, E., & Tian, Z. (2020). Green warehousing, logistics optimization, social values and ethics and economic performance: the role of supply chain sustainability. *The International Journal of Logistics Management,* 31(3), 549-574. doi:10.1108/ijlm-10-2019-0275

Ali, I. & Phan, H. M. (2021). Industry 4.0 Technologies and Sustainable Warehousing: A Systematic Literature Review. The International Journal of Logistics Management, 33(2), 644-662. doi:10.1108/ijlm-05-2021-0277

Ali, P. J. M. & Faraj, R. H. (2014). Data normalization and standardization: a technical report. *Machine Learning Technical Reports*, 1(1), 1-6. doi:10.13140/RG.2.2.28948.04489

Amjed, T. W., & Harrison, N. J. (2013). A Model for sustainable warehousing: from theory to best practices. *In Proceedings of the International Decision Sciences Institute and Asia Pacific DSI Conference* (pp. 1-28). Towson: Decision Sciences Institute.

Anand, V., Lee, S., & Prabhu, V. V. (2014). Energy-aware models for warehousing operations. In: Grabot, B., Vallespir, B., Gomes, S., Bouras, A., Kiritsis, D. (eds), *Advances in Production Management Systems. Innovative and Knowledge-Based Production Management in a Global-Local World. APMS 2014. IFIP Advances in Information and Communication Technology*, vol. 439. Berlin, Heidelberg: Springer. doi:10.1007/978-3-662-44736-9_48

Bartolini, M., Bottani, E., & Grosse, E. H. (2019). Green warehousing: Systematic literature review and bibliometric analysis. *Journal of Cleaner Production,* 226, 242-258. doi:10.1016/J.JCLEPRO.2019.04.055

Boenzi, F., Digiesi, S., Facchini, F., Mossa, G., & Mummolo, G. (2016). Greening activities in warehouses: a model for identifying sustainable strategies in material handling. In B. Katalinic (Ed.), *Proceedings of the 26th DAAAM International Symposium.* Vienna: DAAAM International. doi: 10.2507/26th.daaam.proceedings.138

Buntak, K., Kovačić, M., & Mutavdžija, M. (2019). Internet of things and smart warehouses as the future of logistics. *Tehničkiglasnik*, 13(3), 248-253. doi:10.31803/tg-20190215200430

Burinskiene, A., Lorenc, A., & Lerher, T. (2018). A simulation study for the sustainability and reduction of waste in warehouse logistics. *International Journal of Simulation Modelling*, 17(3), 485-497. doi:10.2507/IJSIMM17(3)446

Carli, R., Digiesi, S., Dotoli, M., & Facchini, F. (2020). A control strategy for smart energy charging of warehouse material handling equipment. *Procedia Manufacturing*, 42, 503-510. doi:10.1016/j.promfg.2020.02.041

Đukić, G., Česnik, V., & Opetuk, T. (2010). Order-picking methods and technologies for greener warehousing. *Strojarstvo: časopis za teoriju i praksu u strojarstvu,* 52(1), 23-31.

Freis, J., Vohlidka, P., & Günthner, W. A. (2016). Low-Carbon warehousing: Examining impacts of building and intra-logistics design options on energy demand and the CO2 emissions of logistics centers. *Sustainability*, 8(5), 448. doi:10.3390/SU8050448

Füchtenhans, M., Glock, C. H., Grosse, E. H., & Zanoni, S. (2021). Using smart lighting systems to reduce energy costs in warehouses: A simulation study. *International Journal of Logistics Research and Applications*, 1-19. doi:10.1109/CoDIT.2019.8820539

Gibberd, J. (2021). Green Building Technologies. *In Research Anthology on Environmental and Societal Well-Being Considerations in Buildings and Architecture (pp. 1-24).* Hershey: IGI Global. doi: 10.4018/978-1-7998-9032-4.ch001

Grzybowska, K., Awasthi, A., & Sawhney, R. (Eds.). (2020). *Sustainable Logistics and Production in Industry 4.0: New opportunities and challenges*. Cham: Springer. doi:10.1007/978-3-030-33369-0

Gülmez, Y. S. & Rad S. T. (2017). Green logistics for sustainability. *International Journal of Management Economics & Business/UluslararasiYönetimIktisatveIsletmeDergisi,* 13(3), 603-614. doi:10.17130/ijmeb.2017331327

Iancu, I. E., & Moga, L. M. (2022). Life cycle analysis of warehouse-type constructions. In *CLIMA 2022 conference*. Delft: TU Delft OPEN. doi:10.34641/clima.2022.329

Jayarathna, C. P., Agdas, D., & Dawes, L. (2022). Exploring sustainable logistics practices toward a circular economy: A value creation perspective. *Business Strategy and the EnvironmentI* 32(1), 704-720. doi:10.1002/bse.3170

Joshi, A., Kale, S., Chandel, S., & Pal, D. K. (2015). Likert scale: Explored and explained. *British journal of applied science & technology*, 7(4), 396-403. doi: 10.9734/BJAST/2015/14975

Kadam, S., Karvekar, A., & Kumbhar, V. (2017). Traditional & green supply chain management–A review. *International Advanced Research Journal in Science, Engineering and Technology*, 4(1), 38-39. doi: 10.17148/IARJSET/NCDMETE.2017.11

Kamali, A. (2019). Smart warehouse vs. traditional warehouse. *CiiT International Journal of Automation and Autonomous System*, 11(1), p. 9-16. doi:10.36039/ciitaas/11/1/2019/180349.9-16

Kuhlman, T., & Farrington, J. (2010). What is sustainability? *Sustainability*, 2(11), 3436-3448. doi:10.3390/SU2113436

Lewczuk, K. & Kłodawski, M. (2020). Logistics information processing systems on the threshold of IoT. *Scientific Journal of Silesian University of Technology*. *Series Transport*. 107, 85-94. doi: 10.20858/sjsutst.2020.107.6

Lewczuk, K., Kłodawski, M., &Gepner, P. (2021). Energy consumption in a distributional warehouse: A practical case study for different warehouse technologies. *Energies*, 14(9), 2709. doi:10.3390/en14092709

Malinowska, M., Rzeczycki, A., & Sowa, M. (2018). Roadmap to sustainable warehouse. *SHS Web of Conferences*, 57, p. 01028. doi:10.1051/SHSCONF/20185701028

Modica, T., Perotti, S., & Melacini, M. (2021). Green Warehousing: Exploration of Organisational Variables Fostering the Adoption of Energy-Efficient Material Handling Equipment. *Sustainability*, *13*(23), 13237. doi:10.3390/su132313237

Mulder, S. (2013). *Sustainable warehousing: an empirical research at Unilever on building options and collaboration models in sustainable warehousing* (Master's thesis). Enschede: University of Twente.

Mumba, D. C. (2020). *A comparison of automated warehouse with traditional warehouse management: a case study of DMNU in Zambia* (Doctoral dissertation). Lusaka: Cavendish University Zambia.

Petersen, B. (2022, June 20). *Create a Sustainable Warehouse with Reusable Packaging.* Accessed on 15. July 2022 https://www.sdcexec.com/warehousing/packaging/article/22288548/orbis-corporation-create-a-sustainable-warehouse-with-reusable-packaging

Pongrácz, E. (2007). The environmental impacts of packaging. In M. Kutz (ed.) *Environmentally conscious materials and chemicals processingI* (p. 237-278). Hoboken: Wiley. doi:10.1002/9780470168219.ch9

Richnák, P., & Gubová, K. (2021). Green and reverse logistics in conditions of sustainable development in enterprises in Slovakia. *Sustainability*, 13(2), 581. doi:10.3390/su13020581

Ries, J. M., Grosse, E. H., & Fichtinger, J. (2017). Environmental impact of warehousing: a scenario analysis for the United States. *International Journal of Production Research*, 55(21), 6485-6499. doi: 10.1080/00207543.2016.1211342

Sammut-Bonnici, T. & Galea, D. (2015). SWOT analysis. In C. L. Cooper, J. McGee and T. Sammut-Bonnici (Eds.), *Wiley Encyclopedia of Management.* Chichester: Wiley. doi:10.1002/9781118785317.weom120103

Saroha, R. (2014). Green logistics & its significance in modern day systems. *International Review of Applied Engineering Research*, 4(1), 89-92.

Storgärd, K. (2021). Green 3PL Warehousing-A case study of how Kuehne Nagel Sweden's warehousing operations can become green. (Master's thesis). Gothenburg: School of Business, Economics and Law.

Wahab, S. N., Shakrein Safian, S. S., Othman, N., & Mohamad Azhar, N. A. (2021). Motivations To Implement Sustainable Warehouse Management: A Literature Review. *International Journal of Accounting, Finance and Business* (IJAFB), 6 (33), 109 - 117.

Wahyuni, F. D., Najah, Z., & Santoso, M. I. (2022). Mapping of sustainable warehouse process in the agro-hub Banten using business process modelling notation. *IOP Conference Series: Earth and Environmental Science* 978(1), 012053. doi:10.1088/1755-1315/978/1/012053

Yang, L., Zhang, H., Shen, H., Huang, X., Zhou, X., Rong, G., & Shao, D. (2021). Quality assessment in systematic literature reviews: A software engineering perspective. *Information and Software Technology*, *130*, 106397. doi: 10.1016/j.infsof.2020.106397

Żuchowski, W. (2015). Division of environmentally sustainable solutions in warehouse management and example methods of their evaluation. *LogForum*, *11*(2), 171-182. doi:10.17270/J.LOG.2015.2.5

AUTHORS

A. Anita Vasileva, M.Sc.ME., is a PhD student at the Ss. Cyril and Methodius University in Skopje, Faculty of Mechanical Engineering-Skopje. Her main research interest is in transport mechanization, material handling equipment and logistics (e-mail: anita.vasileva@mf.edu.mk).

B. Ana M. LAZAREVSKA, D.Sc. ME., is affiliated to the Faculty of Mechanical Engineering, part of the Ss Cyril and Methodius University, Skopje, Macedonia. Her main research interest is in sustainable development, environmental engineering, industrial energy efficiency and energy management (e-mail: ana.lazarevska@mf.edu.mk).

C. Kristina Jakimovska, D. Sc. ME, is an Associate Professor at the Ss. Cyril and Methodius University in Skopje - Faculty of Mechanical Engineering- Skopje. The areas of her interest are reliability of technical systems; logistics; exploitation and maintenance of machinery and equipment (kristina.jakimovska@mf.edu.mk).

Manuscript received by 28 th July 2022.

The authors alone are responsible for the content and writing of this article.

Ustrezna merila za prehod s konvencionalnega na trajnostno skladiščenje

Izvleček - Ta članek obravnava postopek izbire meril, ki so najprimernejša za prehod s konvencionalnega na trajnostno skladiščenje. Analiza SWOT je uporabljena za poudarjanje slabosti konvencionalnega in prednosti trajnostnega skladiščenja, da bi izbrali najprimernejše, za tukaj predstavljeno študijo. Rezultate smo preverili z vprašalnikom, ki so ga izpolnili strokovnjaki iz področja ekonomije, logistike, skladiščenja in strojništva. Rezultati so podali pet najpomembnejših meril za preoblikovanje konvencionalnega v trajnostno skladiščenje. Ugotovili smo, da so obnovljivi viri energije najpomembnejše merilo za preoblikovanje konvencionalnega skladiščenja v trajnostno po okoljskih vidikih, pametna tehnologija pa je nad vsemi drugimi merili po ekonomskih vidikih. Poleg tega sta zagotavljanje osebne zaščitne opreme ter redno servisiranje strojev in vozil dve glavni merili z družbenega (varnostnega) vidika.

Ključne besede - logistika, trajnostno skladiščenje, analiza SWOT, obnovljiva energija