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Katarzyna WŁODARCZYK[1], Agata GÓRSKA[2]

USING ARTIFICIAL INTELLIGENCE IN SUSTAINABLE MANUFACTURING – A CASE STUDY OF NORTHWOOD PALLETS PRODUCER LLC

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The article focuses on one of the modern technological tools – artificial intelligence (AI) and its use in an enterprise that operates in accordance with the principles of sustainable development. The aim of the study is to assess the use of artificial intelligence in the operations of a manufacturing company. The article is based on the experience of the Polish company Northwood Pallets Producer LLC (a manufacturer of wooden packaging). A comparison of three key areas shows the synergistic impact of AI on the production process at Northwood, visible from material analysis, through thermal protection of the product, to energy control. The company has not only implemented AI, but built it into its sustainable strategy, strengthening the existing pillars of its operations, i.e. through increased material efficiency, a focus on more favourable low-emission indicators, energy savings, reduced operating costs, and improved product quality, not only by introducing new solutions, but also by including these solutions in the product description and. Thus, the example of Northwood Pallets Producer LLC shows how integrating artificial intelligence in sustainable production processes can lead to improvements in operational efficiency, cost reductions and support for the sustainable development strategy.

Keywords: sustainable development, modern technologies, production process, artificial intelligence, sustainable manufacturing

[1] University of Szczecin, Department of Marketing. ORCID: 0000-0002-6020-8378.
[2] Northwood. ORCID: 0000-0001-5626-8928.

1. INTRODUCTION

Deeper considerations on the implementation of sustainable development activities are constantly in the sphere of interest of both researchers and practitioners. The concept of sustainable development describes the process within which it is possible to achieve a high quality of life for residents in the long term while respecting natural resources and nature. At the same time, it is possible to take into account development in the social, economic and spatial sphere. Development is achieved by implementing a 'sustainable order'– a model of development integrating all dimensions of sustainable development – economic, social, environmental and institutional-political (UN, 2024a; Teneta, 2024).

Sustainable development is related to technological development as a process of supporting contemporary management principles through the creation of inventions and innovations, along with the dissemination of new and modern technologies. The importance of technological development in shaping the contemporary economy results from it being treated as a significant factor in changes in the degree of innovation and competitiveness at every level of operations, starting from the micro (in relation to companies) and ending at the macro level (in relation to economies) (Mateusiak, Stoma, 2020; Zakrzewska, Jarosz, 2022). The use of modern technologies allows a company to produce goods and services faster, cheaper, and often better in terms of quality. However, in addition to improving the products and services they offer, technologies help companies manage their resources efficiently and optimize organizational functioning at all its levels (Łaszek, 2018; Boratyńska et al., 2021; Ratnicyn, 2016; Bartnik, 2016; Cenkier, 2024).

This study focuses on one of the modern technological tools – artificial intelligence (AI), and its use in an enterprise that operates in accordance with the principles of sustainable development. It aims to assess the use of artificial intelligence in the operations of a Polish manufacturing company, Northwood Pallets Producer LLC (a manufacturer of wooden packaging). In order to achieve the research goal, the first part of the article presents selected aspects of the literature on the subject of sustainable development and artificial intelligence. Following this, activities in the field of the use of artificial intelligence in Northwood production processes are presented in order to implement sustainable production. The empirical part of the article uses materials provided by Northwood in the form of internal company materials for the years 2024-2025.

2. AI IN THE SUSTAINABLE PRODUCTION PROCESS – THEORETICAL CONSIDERATIONS

Artificial intelligence is transforming the manufacturing industry in a way that is significantly different from the standards adopted in the 20th and early 21st centuries. On the one hand, implementing AI in production opens up new possibilities

for process optimization and increasing both the efficiency and quality of products and services; on the other, it supports the implementation of the concept of sustainable development.

According to the resolution, sustainable development meets basic human needs while preserving, protecting and restoring health, thus maintaining the balance of the Earth's ecosystem without compromising the ability of future generations to meet their needs. The 17 goals of the 2030 Agenda concern the following aspects: no poverty; zero hunger; good health and well-being; good quality education; gender equality; clean water and sanitation; clean and affordable energy; economic growth and decent work; innovation, industry, infrastructure; reduced inequalities; sustainable cities and communities; responsible consumption and production; climate action; life below water; life on land; peace, justice and strong institutions; partnerships for the goals. One of these 17 Sustainable Development Goals focuses on ensuring sustainable consumption and production patterns. Goal 12 refers to promoting the efficient use of energy and other resources, supporting sustainable infrastructure, and ensuring access to basic services, decent jobs, including in the environmental sector, and a better quality of life. It encompasses three dimensions: economic, social and environmental. Particular attention is paid to reducing resource consumption and the scale of degradation and pollution (UN, 2024b; Muinzer, Mackie, 2024).

As part of the goals implemented for sustainable development, an important aspect from the perspective of the company is to organise production processes in accordance with the goals of the 2030 Agenda. According to the EPA (United States Environmental Protection Agency), sustainable production means "creating products manufactured using economically viable processes that minimize negative impacts on the environment while saving energy and natural resources. Sustainable production also increases the safety of employees, communities and products" (EPA).

In a broader practical and theoretical sense, sustainable production can be described as all actions and decisions concerning the method of producing goods and services that at all stages of the product life cycle (creation, introduction to the market, growth, maturity, decline), as well as at each stage of the production process (from the moment of its planning, through its implementation, distribution and at other stages depending on the specificity of the activity), ecological and social aspects are taken into account more than the existing standard, conventionally used production methods. It is a multidimensional, holistic approach to the production process, in which the following aspects can be observed to be balanced: efficient use of energy sources (e.g. renewable energy), rational use of other resources (e.g. water, wind), promoting an economy that does not harm the climate (e.g. reducing exhaust emissions), reducing the amount of production waste, supporting local communities, promoting sustainable infrastructure, creating good working conditions, improving the quality of life in the workplace, building relationships based on partnership, maintaining standards and certifying one's activities, taking care of competitiveness,

ethics, as well as raising the level of creativity and innovation, using the achievements and possibilities of artificial intelligence, including (Acerbi, Taisch, 2020; Vinante al., 2021; Viles et al., 2022; Zwiech, 2024; Nowakowska, 2024).

The European Parliament defines artificial intelligence as the ability of machines to demonstrate human skills, such as reasoning, learning, planning and creativity. Artificial intelligence enables technical systems to perceive their environment, cope with what they perceive and solve problems by working towards a specific goal. The computer receives data (already prepared or collected by its sensors, e.g. a camera), processes it, analyses it and responds (European Parliament, 2025b). Artificial intelligence (AI) is also becoming the most important condition for modern production management in modern enterprises, because it allows for traditional production processes to be transformed into more integrated and operationally efficient ones. Thanks to artificial intelligence, it is possible not only to automate, but also to optimize aspects of production, such as quality control and maintenance, optimal use of resources, or management of the production chain and supply chain, as well as supporting employees and improving their working conditions. Regardless of the direction in which artificial intelligence will develop, we can certainly talk about many conveniences and advantages of its use in relation to the enterprise and running a business, because artificial intelligence can enable the development of a new generation of products and services, as well as support pro-ecological activities, increase sales, improve machine maintenance, production efficiency and quality, customer service, and also save energy (European Parliament, 2025a; Otręba, 2024).

It is worth remembering, however, that when using AI tools and capabilities, the possibility of using standard, commonly used procedures should be taken into account. Conversely, in the case of specific production, methods, tools and activities in the field of automation, robotization and artificial intelligence should often be individualized in terms of the specificity of production (Nilsson, 2014; Cioffi et al., 2020; Czarnitzki, Fernández, Rammer, 2023; Lin et al., 2024).

The next part of the study will present an example of a Polish company – Northwood Pallets Producer LLC – from the wood production industry. This company uses artificial intelligence tools in its operations for the needs of its own production, while implementing the assumptions of the concept of sustainable development.

3. APPLICATION OF AI SOLUTIONS IN SUSTAINABLE PRODUCTION – THE PRODUCTION PROCESS AT NORTHWOOD PALLETS PRODUCER LLC

Northwood Pallets Producer LLC is a Polish family business based in Strzykocin (West Pomeranian Voivodeship), which specialises in the production of wooden pallets and wooden components. The company was established over twenty years ago and has been continuously operating, initially under the name Northwood, and for

several years as a limited liability company, and has been managed by successive generations of the family.

In response to changes in the economic and social, but also technological and ecological environment, for many years Northwood has sought to deepen its implementation of sustainable production strategy. In Northwood, this term is understood as rational and environmentally responsible management of wood raw materials, waste minimization, and the use of renewable energy sources, while implementing processes that are compliant with the requirements of international markets, especially in terms of phytosanitary and ecological standards. One of the steps in revolutionizing the production processes at Northwood was the introduction of the Circular Economy (CE). The use of this innovative concept was intended not only to significantly reduce waste generation, but also effect more efficient use of wood raw materials. In addition, as part of raising ecological standards, Northwood used recycling and reuse in the production of unused waste to minimize the consumption of wood raw materials, balance production and reduce its negative impact on the natural environment. In order to minimize wood waste, a production concept was developed. This maximized the use of available wood resources by utilising slivers and sawdust, materials previously regarded as substandard and unnecessary raw materials. Production waste was mainly used to produce semi-finished products, such as MDF boards, briquettes, pallets and pallet cubes. In this way, no part of the tree is wasted. Moreover, at the same time, the company generates no unnecessary waste and reduces its negative impact on the natural environment. This tactic not only enables savings to be made in capital and resources, but also minimizes the costs associated with waste disposal.

In order to reduce carbon dioxide emissions and electricity costs, the company invested in constructing its own photovoltaic power plant. The intention was to use renewable energy from the plant to boost the company's competitiveness on the market and improve air quality in the long term. Powering production from its own photovoltaic power plant was also a key element of the sustainable development strategy. As a result, the power plant cut greenhouse gas emissions and significantly reduced electricity consumption costs. Thus, on the one hand, the power plant contributed to improving the living conditions of local communities and limiting the negative impact of industry on the environment, while on the other, it also gave the company tangible financial benefits. Additional activities supporting an ecological and sustainable style of work and production also resulted in investments and modernization of the machinery necessary for pallet production at Northwood. The current machinery is modern in terms of technology, and also energy-efficient. As a result, the products offered are not only ecologically produced, but are also competitively priced. Another interesting solution is to introduce recuperators and energy recovery systems, which facilitate the effective use of heat generated in the production process. Such action not only results in lower energy consumption, but also allows for lower operating costs.

Pallets are produced in Northwood in accordance with the IPPC certificate regulations and from wood from FSC-certified forests. These activities support both sustainable production and the responsible management of forest resources. Cooperation with the company's suppliers is long-term, and their selection is based on analysing their activities through the prism of the certificates used. Such cooperation initiatives between ecologically responsible producers enhance their credibility on the market, as well as the attractiveness of products for customers seeking ecological and sustainable solutions.

Another activity fostering sustainable production at Northwood involves R&D (Research and Development) initiatives. The continuous search for innovative solutions and improvements in production processes are key to maintaining Northwood's leading position in the wood industry and adapting to changing market conditions and customer expectations. Therefore, employees cooperate with the scientific and academic community and other companies to search for new technologies and practices facilitating the efficient use of wood resources. The results of this research are used to further develop and improve production processes, as well as to introduce innovative products that fully meet the requirements related to environmental protection and efficiency of use. Work is underway to implement a closed product cycle to maximise the use of raw materials and reduce the amount of production waste.

It is also worth emphasizing Northwood's owners' awareness that the company's sustainable development is only possible thanks to the commitment and skills of all employees. For this reason, investments are being made in education and training in environmental protection, the rational management of available resources, and modern production technologies. In addition, Northwood cooperates with local communities on local projects and initiatives that contribute to environmental protection and sustainable development. In this way, value is created not only for the company itself, but also for the communities, customers and suppliers with whom Northwood cooperates.

In 2024, the company took the next step in its development and decided to implement solutions based on artificial intelligence (AI) as support and as a tool for optimizing sustainable production. The aim was to streamline operations by automating key production processes, increasing material and energy efficiency, and reducing operating costs, all in the spirit of "smart growth" based on data and technology.

One of the first aspects of production in which artificial intelligence tools were used was wood cutting, in which the AI-assisted IMH machine was used. In the traditional model of pallet production, humans played a huge role. The machine operator had to evaluate each piece of wood independently, and either qualify it for production or reject it. The operator was also required to take orders into account, know the structure of the raw material, predict consumption and minimize waste. With all this, it was easy to make mistakes or to waste material,

especially in the case of less experienced employees. Based on its extensive experience, Northwood identified this stage as key to the efficiency of the entire production cycle. The response was to implement a modern machine from the Swedish brand IMH, which not only cuts wood, but above all analyses it and makes production decisions based on artificial intelligence algorithms. The machine scans each pile of wood for its dimensions, density and material structure, compares the data with the order database, and selects the optimal cut. Then it compares the data with the order database and selects the optimal cut (i.e. boards, blocks, side elements). In addition, the IMH machine recognizes lower-quality wood and is able to redirect it to another use (e.g. for producing the inner layers of pallets). Importantly, thanks to these AI systems, the IMH wood cutting machine minimizes waste by generating a cutting plan that ensures maximum use of all available wood material. Such a solution not only allows the amount of waste to be reduced and the raw material to be used rationally, but also replaced the three previous machines (for cutting, selection and assembly) with one, while in the case of employees, employment was limited to two people instead of four. Importantly, the new solution required no ongoing supervision of the production process, since the artificial intelligence system controls the production process independently. The use of the IMH machine with the AI system allowed the company to increase its material efficiency by 30% within a year, as well as to reduce the costs of raw material and waste. In addition, these changes shortened the production cycle time and reduces the employee workload. Moreover, it was also possible to process wood of different quality without compromising product quality.

After successfully streamlining elements of production management using AI-powered machines, the technology was also applied to other aspects of the business. Drying is a key process for every exporter of wooden pallets, especially to markets such as Denmark, Germany or outside Europe, where phytosanitary standards are required (IPPC certificate). Pallets must have a moisture content of no more than 22% and undergo appropriate thermal processing. For this reason, Northwood implemented an AI-assisted drying system that monitors each batch of pallets and selects drying parameters dynamically, economically and precisely. The machines scan each pallet and, based on the type of wood, its moisture content and the number of elements, the optimal drying programme is determined. The system works with recuperation (energy recovery from water vapor) and is powered by its own photovoltaic installation. The energy goes directly to the drying chamber. Implementing this solution allowed the drying time to be shortened by approx. 10-15% (depending on the initial humidity). Gas consumption was also cut by approximately 20% compared to the previous consumption, thus maintaining high quality and compliance with export standards, and reducing CO_2 emissions, all thanks to the use of renewable energy sources and heat recovery.

AI-supported systems have also been used in energy management processes. Northwood has been investing in green energy for years, and has its own photovoltaic power plant. The OPTIMA system integrates Northwood's energy infrastructure with all production processes. AI analyses energy demand in real time (for production and drying processes, as well as for the company's administration) and manages energy supply priorities. Energy from its own photovoltaic power plant is distributed according to need. As a rule, energy first flows to the drying plant, then to production machines and the company's office, and only then to the external network. At the same time, the system minimizes energy transmission costs and reduces losses thanks to intelligent internal distribution. Additionally, the system allows for reporting, forecasting and better planning of energy use based on weather conditions. The primary measurable effects of using AI in the case of the OPTIMA system are a 30% reduction in annual energy costs, and increased energy self-sufficiency (up to 80-90% in the summer), as well as an improvement in energy stability, a crucial factor in production and supply planning.

Table 1 presents the effects of AI implementation at Northwood in selected aspects of its operations, while figure 1 indicates the production benefits resulting from the use of AI in the production process.

Table 1. Effects of AI implementation in production processes at Northwood

AI implementation area	Main effect of implementing AI	Additional effect of implementing AI
Wood cutting – IMH machine	Increased material efficiency (up 30%)	Reduction in the number of machines (from 3 to 1) and operators (from 4 to 2)
Drying process	Reduced drying time (down 10-15%) and reduced gas consumption (down 20%)	
Energy management – OPTIMA system	Reduced energy costs (down 30%) and therefore increased production efficiency	Efficient use of renewable energy (energy self-suffiency up to 80-90% in the summer)

Source: own study based on internal documents of Northwood company.

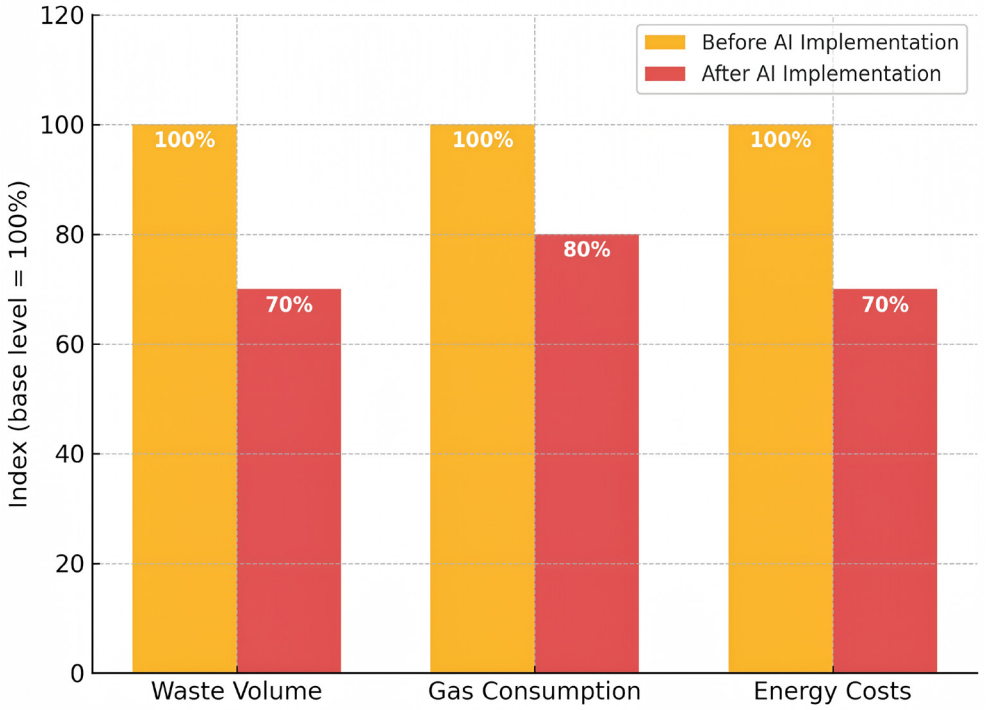

Fig. 1. Impact of AI on Key Production Indicators at Northwood (own study based on internal documents of Northwood company)

The comparison of three key areas shows the synergistic impact of AI on the production process at Northwood, visible from material analysis, through thermal protection of the product, to energy control. The company not only implemented AI, but built it into its sustainable strategy, strengthening the existing pillars of its operations. These include increased material efficiency, focusing on more favourable low-emission indicators, energy savings, improved product quality not only due to introducing new solutions, but also by including the solutions used in the product description and reduced operating costs. Thus, the example of Northwood Pallets Producer LLC shows that integrating artificial intelligence in sustainable production processes can lead to significant improvements in operational efficiency, cost reductions, and support for the sustainable development strategy. The technological solutions implemented there not only increased the Northwood's competitiveness on the international market, but also contributed to environmental protection through effective resource management.

4. CONCLUSIONS

More and more companies treat "sustainable development" as an important goal in their strategy and activities to increase growth and global competitiveness. This trend has expanded beyond traditionally "green" companies and now includes many smaller and larger companies in various industrial sectors. In many cases, the application of a sustainable development strategy produces significant results, primarily greater operational efficiency through cost and waste reduction, meeting customer expectations and thus increasing competitive advantage in the market, building public trust, building the brand's image and its reputation, creating a long-term corporate strategy in which not only a positive financial result but also broadly understood success plays an important role. In sustainable development activities, however, companies must be open to all market innovations that can support the goals they pursue. Artificial intelligence is undoubtedly one of such contemporary possibilities for a dynamic manufacturing company.

The article presents an example of a Polish manufacturing company that has used AI tools in its operations. The implementation of solutions based on artificial intelligence at Northwood Pallets Producer LLC is an example of the conscious and effective use of technology in the service of sustainable industrial production. When analysing the impact of AI on individual areas of the company's operations, it can be stated that the changes were systemic in nature, covering not only the technological but also organizational, economic and environmental aspects. The use of AI in the wood cutting process resulted in a significantly improved material efficiency, a reduction in waste, and also the better use of lower quality raw materials, which could previously be regarded as substandard. In terms of pallet drying, the integration of the AI system with recuperation and energy obtained from photovoltaics enabled a dynamic adjustment of process parameters to variable conditions and improvements in many indicators (mainly time and consumption). The third pillar of the implementation related to the OPTIMA energy management system, which enabled renewable energy sources to be integrated with the current energy demand in the plant. As a result, the company is less dependent on external suppliers and more resistant to fluctuations in energy prices. The integrated approach to implementing AI at Northwood Pallets shows that technology is not an end in itself, but a tool to rationalize resources, reduce costs and increase competitiveness in a sustainable manner. The company has not only optimized its production processes, but also made data and algorithms a key element of its strategy. This can act an inspiration for other industrial companies seeking a balance between innovation and environmental responsibility.

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WYKORZYSTANIE SZTUCZNEJ INTELIGENCJI W PRODUKCJI ZRÓWNOWAŻONEJ – STUDIUM PRZYPADKU FIRMY NORTHWOOD PALLETS PRODUCER SP. Z O.O.

Streszczenie

Artykuł koncentruje się na jednym z nowoczesnych narzędzi technologicznych – sztucznej inteligencji (AI) – oraz jej wykorzystaniu w przedsiębiorstwie działającym zgodnie z zasadami zrównoważonego rozwoju. Celem badania jest ocena wykorzystania AI w działalności przedsiębiorstwa produkcyjnego. Publikacja została opracowana na podstawie doświadczeń polskiej firmy Northwood Pallets Producer sp. z o.o. (producenta opakowań drewnianych). Porównanie trzech kluczowych obszarów pokazuje wpływ AI na proces produkcyjny w Northwood, widoczny od analizy materiałowej, poprzez ochronę termiczną produktu, po kontrolę energetyczną. Firma nie tylko wdrożyła AI, ale także wbudowała ją w zrównoważoną strategię, wzmacniając dotychczasowe filary swojej działalności, tj.: zwiększoną efektywność materiałową, skoncentrowanie się na korzystniejszych

wskaźnikach niskoemisyjnych, zaoszczędzoną energię, poprawę jakości produktu nie tylko poprzez wprowadzenie nowych rozwiązań, ale również poprzez uwzględnienie zastosowanych rozwiązań w opisie produktu oraz obniżenie kosztów operacyjnych. Tak więc przykład Northwood Pallets Producer sp. z o.o. pokazuje, że integracja sztucznej inteligencji w zrównoważonych procesach produkcyjnych może prowadzić do poprawy efektywności operacyjnej, redukcji kosztów i wsparcia strategii zrównoważonego rozwoju.

Słowa kluczowe: zrównoważony rozwój, zrównoważona produkcja, proces produkcyjny, nowoczesne technologie, sztuczna inteligencja