

Sustainable production strategies in agricultural transport: Balancing economic efficiency and environmental impact

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Abstract: *Purpose.* This paper aims to present a sustainable production strategy for manufacturing parts and components for agricultural transport means, focusing on minimising production costs and post-production waste generation. *Methodology.* The research employs a case study approach, using participant observation and analysis of a manufacturing company's specific production process for an agricultural trailer floor panel. The authors propose a model for optimising raw material selection and utilising post-production waste to achieve economic and environmental savings. *Results.* The results demonstrate that by selecting the appropriate raw material dimensions and implementing a product diversification strategy to utilise post-production waste, the manufacturer can reduce material costs and environmental losses while generating additional revenue streams. *Theoretical contribution.* The study contributes to sustainable production management by proposing a practical strategy model that balances economic efficiency and environmental concerns in manufacturing agricultural transport components. The model emphasises the importance of raw material selection, waste minimisation, and product diversification to achieve sustainability goals. *Practical implications.* The findings provide valuable insights for manufacturers in the agricultural transport sector, highlighting the potential benefits of adopting sustainable production strategies. The proposed model can be implemented in practice to optimise resource utilisation, reduce waste generation, and improve overall economic and environmental performance.

Keywords: parts and components of agricultural trailers, sustainable production, means of agricultural transport, economy and environment

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1. Introduction

The development of management concepts and methods should consider the variability of the conditions in which enterprises operate (Trzcieliński, Włodarkiewicz-Klimek & Pawłowski, 2013). In a sustainable economy, companies seeking to improve their competitiveness should base their activities on their readiness to respond to market needs and expectations, stemming from the ability to integrate diversified and independent capabilities of the company into a new quality, a new whole (Lisiecka, 2011). The outcomes of the improvement process should lead to an increase in the efficiency of machines and devices, the optimisation of material flow, the shortening of production times, the minimisation of inventories and greater employee satisfaction, and, consequently, the improvement of the company's technical culture. This is achieved through a structured, methodological approach to all processes and employees' willingness to partake in continuous improvement (Idobayeva, 2020). The basis for the success of an organisation lies in establishing clear company goals (Kotlar, De Massis, Wright & Frattini, 2018), an intelligible concept of operation and consistent implementation of this in practice (Kraus, Kauranen & Reschke, 2011).

The research discussed in this study is concerned with manufacturers of parts and components of agricultural transport means, which are dedicated to the initial assembly, and with the secondary market (replacements) on the other. In the above context, it was necessary to respect sector-specific requirements. Even more so, the speed and depth of changes in the agricultural machinery sector and the transformation of the conditions for the operation and development of enterprises have resulted in the need to undertake permanent reorganisations in production processes. Improving production (Pacheco, Pergher, Jung & ten Caten, 2014) thus constitutes a great challenge for manufacturers of parts and components of agricultural transport means and is a serious problem in the management of complex production processes (Korneev, Al-Saeedi, Al-Sabry & Nagi, 2014). Increasingly, manufacturers face the dilemma of shortening the life cycle of products (Yurtsever, 2023) while responding to higher consumer expectations regarding equipment quality (Suchánek, Richter & Králová, 2014) as well as the need to reduce costs (Akeem, 2017) and minimise environmental losses (Yang et al., 2023). Hence, sustainable production systems are implemented, actively incorporating the entire range of tools and methods related to the improvement of production processes.

As a result of fierce competition in the market for manufacturers of parts and components of agricultural transport, a certain degree of balance can be observed among market leaders. Manufacturers offer similar products under similar purchase conditions. The authors of the study noticed that it is difficult for the companies to gain an advantage over competitors in terms of technological development or the type of marketing activities performed, as even at this stage, the levels are equalised in a relatively short time - companies have similar opportunities to access the latest developments.

Therefore, the authors recommend that the competitive advantage within the group of closest rivals is determined by the scope and ability to develop sustainable production strategies in the market. The production process should be managed consciously, and the opportunities for its improvement should be focused on. The priority should be awarded to a sustainable strategy involving the following:

- Reducing the amount of waste in a given production process, achieved through the correct selection of materials, significantly reduces production costs and, thus, environmental losses.
- Post-production waste generated from a given process should be maximally used in other implementation processes (in this way, the manufacturer generates additional revenues, which undeniably affect the profit generated).
- Achieving the highest possible productivity in the manufacturing process is central to the company's value.

In this study, it was considered justified to present a model of a sustainable production strategy that can be applied in management practice. In the context of the above, the authors suggest:

- Presentation of key issues regarding sustainable manufacturing strategy (a brief description);
- Illustrating the impact of the correct selection and use of raw materials on economic results and minimising environmental losses (generation of unnecessary waste). For this purpose, variants of raw material cutting in the agricultural trailer floor panel production process will be suggested and will constitute the subject of participant observation.

The value of the study is in the practical implementation of the sustainable production model, hence the presentation of the results of the strategy implementation in one of the manufacturing enterprises in the sector related to the production of agricultural means of transport. Additionally, due to its destructive impact on the environment, transport has become the focus of attention when it comes to sustainable development, consequently leading to the development of sustainable transport (Ambroziak et al., 2014; Jacyna, 2009).

2. The method concept

A significant number of manufacturers of parts and components of agricultural machines, the constantly growing competition and relatively low barriers to market entry will result in the need to solve "ad hoc" problems that arise at a specific time and space of the enterprise. Its management must, therefore, develop the ability to look at the issue from an innovative point of view, different from the one adopted in the past, liberated from the conventional way of thinking, which should result in the deconstruction of the traditional paradigm and create a new sustainable approach.

The practical observations of the authors of the study lead them to the conclusion that the functioning management systems, in most cases, help reduce the consumption of raw materials and, thus, operating costs and environmental losses. However, their role is mainly to eliminate the losses already incurred. This means that enterprises are in a situation in which efficiently functioning management systems lead to the elimination of losses that occur during the production process. Based on these experiences, the concepts and methods of managing a production enterprise should be created, the primary goal of which is to eliminate losses even before they are sustained in the production process.

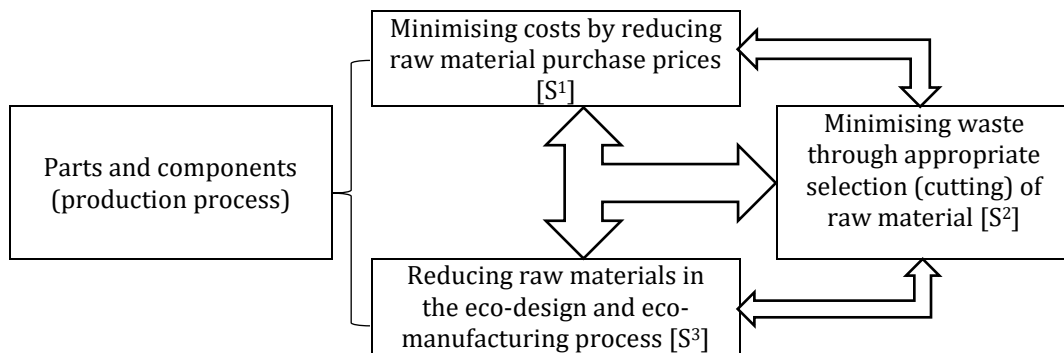
The concept presented by the authors is concerned with the technology design and manufacturing process stage, searching for all actual and potential problems that may arise at the implementation stage. This approach is a component of the process, and it allows for the effective elimination of economic and environmental losses before they are incurred. More importantly, in the presented approach, the definition of production waste itself is expanded: waste is everything the customer does not pay for. This is a new approach to management advocated by the authors of this study, and it involves environmental management.

The method of waste minimisation in the design and organisation of production defined in this publication imposes the obligation to select criteria (such as the quantity, type, or size) that influence the optimal use of the raw material. In the first stage, it is necessary to determine all possible variants of the implementation process and select a solution in view of production possibilities; however, due to the adopted economic criterion (the maximisation of profit), the manufacturer's goal should be striving to develop a manufacturing process that involves the optimal use of existing resources. The manufacturer achieves maximum benefits since minimal expenditure guarantees a quick and high rate of return on the manufactured product.

Therefore, the possibility of achieving market success in today's economy depends on the appropriate selection and effective use of all available resources employed in the production subsystems that are part of the manufacturing enterprise. The complex nature of flexibility is closely related to the multitude of factors (contextual variables) that shape it, which also determine the scope and intensity of its manifestations and effects. Hence, the implementation perspective is particularly interesting, as the most important determinants of product diversification, i.e. the development of a new product, are the main levers of long-term company success. Therefore, the implementation research area should focus on the mechanisms and elements that determine the company's activities and create the competitive advantage already at the design stage.

An expression of the presented approach is an original strategy model assuming the pursuit of savings in the area of raw materials based on the diagnosis of the source of losses, in that way indicating the possibilities of achieving savings in the production process (Figure 1).

Figure 1: Strategy model in the area of raw materials - economic and environmental dimensions



Source: own study.

The presented approach assumes the following: (1) when starting to organise the production process, it should always be borne in mind that the three primary factors of production (i.e. work items, means of work and human labor) must be selected and coordinated in such a way that the products are manufactured in the shortest possible time and in the manner that is most economical and neutral to the environment, (2) the share of each of these factors varies depending on the form and quality of the raw material, the nature of the production process, the degree of mechanisation and automation of production, the efficiency of the means of work, the quality of human work and the degree of organisation of the production process, (3) changing the characteristics of individual factors causes their variable involvement in the production process, which requires their appropriate selection and adaptation to each other (it is therefore about combining the necessary production factors at the right time and place and controlling them and the proportions between them).

Although solving these issues, as they affect the course of the production process, is possible only based on analysing all factors and their parameters, fragmentary research focused on selecting and optimising the raw material was initiated.

3. The subject of research

The research referred to in the study was conducted in a manufacturing company operating in a sector related to agricultural mechanisation. The main activity of the examined company is the production of spare parts and components for agricultural means of transport - mainly tractors and technological trailers.

The company has an implemented quality management system in the field of "production and sale of products processed using plastic and welding methods". It relies on the involvement of all employees to ensure the highest quality and safety of its products. Although the components manufactured bear the EU safety mark "CE" - as a result of the inspections carried out and irregularities identified - it was deemed necessary to verify the current production lines. The observations revealed the possibility of an even more significant adjustment of the process to the currently applicable economic principles and environmental requirements. Whenever a decision on the direction of manufacturing activity should be made on the basis of a good understanding of the conditions and production possibilities based on a thorough economic and environmental calculation of all products, the study presents the results of research work in relation to the product, which is the floor panel of an agricultural trailer T -088 (picture 2) made of sheet metal expressed in figures. The product specification (unit panel, see Fig. 3) is presented in Table 1.

Table 1: Specification of the floor panel of an agricultural trailer - simplified variant

Raw material (mm)	Dimension (mm)	Weight (kg)	Quantity (pcs)	Price (PLN)	Total (PLN)
Sheet 3#	2310x350	19.40	1	3.60	69.84

Source: own study.

Figure 2: Fortschritt T-088 agricultural trailer – a subject of research

Source: www.zpcz.pl

The preliminary analysis of the company's processes revealed a sustainable approach already in place in the production process. The company's inventories are kept to a minimum. Materials and raw materials are delivered directly from suppliers to the places of their application. In addition, project groups improve all processes throughout the enterprise. High visualisation of workplaces makes employees involved in the process of changes and improvements. Machine changeover times are shortened to a minimum (SMED), so there is no need to manufacture large production batches. Maintaining traffic continuity is based on the principles of TPM, i.e. prevention and failure prevention. All areas of the company's operations are subject to measurement processes. The measurement results serve as a basis for making decisions about the state of the enterprise.

4. Waste minimisation and raw material selection – a case study

The type of items produced significantly influences the way of organising production, in addition to the factors that normally determine the way of organising production. These may involve additional features of manufactured items, such as their weight or dimensions, input material, method of organising quality control, processing method, or unit costs of manufactured items. Nowadays, great importance is attached to the economy of production, and that is why items with high unit production costs should be treated as a priority. With those in mind, individual forms of production should be organised to generate lower production costs.

In this part of the study, the authors present the production process of the floor panel of the cargo box of a bulk agricultural trailer (Figure 3), indicating how the appropriate selection of raw material contributes to production costs and environmental losses (post-production waste).

Figure 3: Floor panel of a technological trailer - economic and environmental dimensions

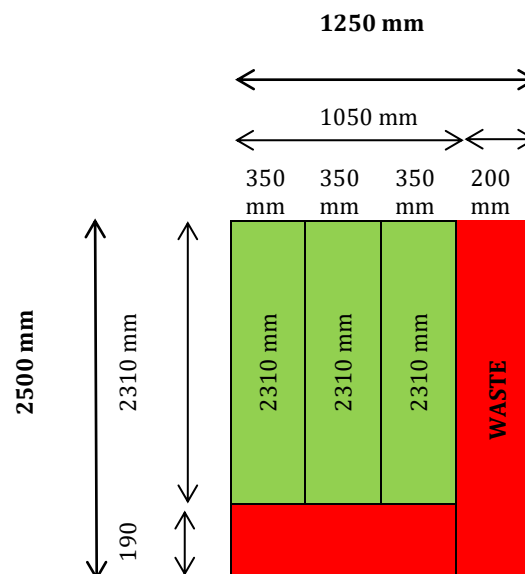
Source: own study.

Participant observation established that the production of the floor panel of the technological trailer is characterised by a relatively low degree of specialisation of workstations. It includes the following: (1) universal machinery adapted to perform plastic forming operations, (2) relatively non-sophisticated production equipment, (3) highly qualified engineering, technical and executive staff, (4) low degree of mechanisation and automation of production, (5) individual nature of technological preparation of production, (6) the need for employees to master a larger number of production activities.

The results of the analyses indicated that the factors influencing the organisation of floor panel production are the principles of material supply, which involve supplying materials based on demand or based on a minimum stock. One of the goals was to look for opportunities to shape the delivery process in a way that would ensure an increase in value. This involves searching for new supply markets and considering alternative forms of implementing the manufacturing process. Determining raw material needs to meet the production needs of the agricultural trailer floor panel consisted of confronting the demand for raw materials for production with the raw material possibilities in this area (selection optimisation).

As part of the supply of raw materials necessary to produce the floor panel of an agricultural trailer, the manufacturer had two options to purchase sheet metal: 3x1500x3000 mm and 3x1250x2500 mm, respectively. By adhering to the principle of optimisation appropriate for the minimisation strategy, i.e. searching for the best relationship between production expenditure and its effects (economic and environmental dimensions), the authors of the study suggested that sheet metal available in 3x1250x2500 dimensions be used in production. Such selection of raw material minimises waste generated in the product manufacturing process, as shown in Figure 4.

Figure 4: Selection of raw material in the production process of the agricultural trailer load box floor panel



Source: own study.

The analyses carried out showed that in the production process of one set of the floor of the cargo box of an agricultural trailer (15 pieces of element with dimensions of 350 x 2310 mm) using sheet metal in the format 3x1250x2500 mm, the purchase of 6 sheets of sheet metal is required with a total weight of 450 kg (the weight of one sheet is 75 kg). The waste generated during sheet metal cutting is 105.64 kg. When purchasing sheet metal in the 3x1500x3000 mm format, the manufacturer generates 303.64 kg of waste.

The research further shows how the post-production waste generated in the process should be transformed into a product of full value.

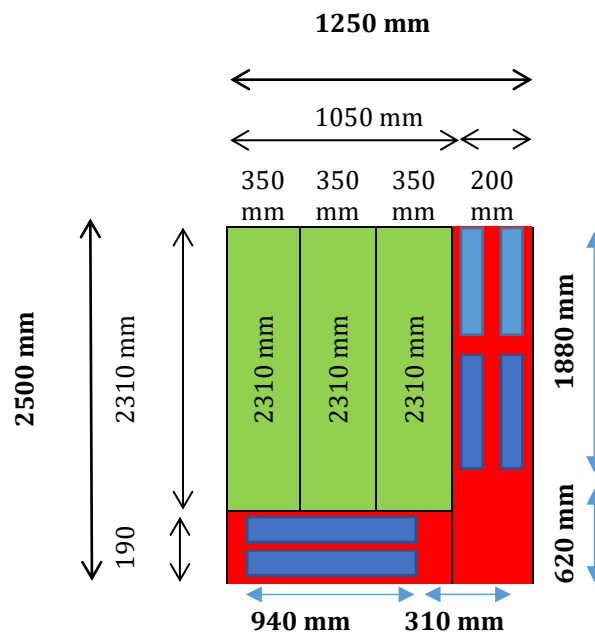
Market analyses conducted by the authors, as well as detailed documentary research,¹ resulted in a catalogue of products that could be implemented within the available raw material resources measuring 200x2500 mm and 190x1050 mm. As a result of the analyses, the decision was made to implement a new product, which was a conveyor strip of an agricultural trailer with dimensions of 3x940x80 mm (Fig. 5). The market price of the product was set at PLN 24.50.

Figure 5: Agricultural trailer conveyor strip and the use of waste in the production process of the agricultural trailer load box floor panel



Source: Fortschritt internal materials.

Figure 6: Use of waste in the production process of the floor panel of an agricultural trailer load box - graphical presentation (indicative)



Source: own study.

As part of the waste unused in the examined production process, the manufacturer can produce 6 pieces of strips from one sheet of metal, which will generate additional revenues of PLN 147.00. Additionally, the decision was made to implement another product, which was a chain clip cover for the agricultural trailer conveyor with dimensions of 3x50x22 mm (Fig. 6). The market price of the product was set at PLN 1.70. As part of this process, the manufacturer obtains 112 pieces of cladding, which results in an additional income of PLN 190.40. The cost of purchasing one sheet of metal is PLN 270.00 net. The revenue from the sale of additional products is at the level of PLN 337.00. Therefore, the manufacturer covers the material costs associated with the production process of the basic product in the form of a floor panel with the product obtained as a result of the proper selection of the raw material.

The concept of minimising post-production waste emphasised by the authors is thus fully affirmed.

¹ The authors analyzed product data sheets of selected products in terms of the possibility of their implementation within the existing post-production waste and technological resources of the examined manufacturing plant.

5. Discussion

In the context of the presented strategy, it is recommended that the selection of appropriate purchasing sources (suppliers) be mandatory. The basic criterion for modeling the strategy should be the pursuit of minimising the total costs related to the purchase of materials and maintaining inventories, as well as creating the basis for uninterrupted production while ensuring the appropriate level of quality of the supplied materials. A reliable assessment and selection of the best suppliers is important throughout the entire life cycle of the company. In this sense, the following considerations shall underlie the selection of a supplier: (1) price of the purchased goods, (2) transport costs, and (3) quality of the purchased goods. The analyses of supplier offers are facilitated by comparative methods based on a rating scale and an established hierarchy of individual assessment criteria.

Based on the research, attention was drawn to the sense and purposefulness of implementing a product diversification strategy (Oladimeji & Udosen, 2019). This means that the company is entering new sectors and thus expanding the scope of its activities in the industry. However, diversification is more than just a simple expansion of the scope of the company's activities. While specialisation is based on the use of a limited repertoire of unique skills, diversification creates the opportunity to apply new skills necessary in the market environment that the company is just beginning to penetrate and to use post-production waste as part of new implementations.

The assumption of the product diversification strategy is based on the company offering a range of new products to existing customers. This involves creating new products and implementing modifications to production processes. Taking this approach ensures that distribution channels are not changed, and the company's previously established position among its existing customers plays a very important role in implementation activities.

The key observations made from the perspective of the research process are:

- Sustainable implementation of agricultural trailer parts and components into the product portfolio is expressed by the manufacturer's ability to effectively select raw materials in relation to key product parameters so that their implementation takes into account economic and environmental goals.
- The presented strategy is an expression of the commonly held belief that economic efficiency and pro-environmental activities guarantee the company's sustainability in line with the current global trend.
- Shaping a sustainable product in the form of trailer parts and components should take place within the dependency model - a product is developed that takes into account the needs of the market as well as identified raw material needs (input resources).
- The offered product should be a compilation of profit and environmental dimensions.
- According to the presented strategy, product knowledge is of key importance, as it is a binding factor generating implementation possibilities, and therefore, the effectiveness of the existing "intellectual capital" shapes the possibility of new implementations.
- Manufacturers wishing to increase the economic efficiency of their resources and production processes should follow the methods and management methods referred to in this study.

Our leading assumption was that balancing production processes is a practical activity, i.e. a conscious and purposeful action of people aimed at their improvement. Therefore, it was considered justified to present the discussed issues from the point of view of economic practice. This approach makes it a useful consideration from the perspective of manufacturers of parts and components of agricultural and other means of transport.

6. Conclusions

Enterprises have come a long way from when environmental protection was practically non-existent to the stage when sustainable development became one of the essential elements of enterprise management (Mensah, 2019). The idea of sustainable development allows the company to go beyond the sphere of its interests related to generating profits. As a result, the company can influence the environment in which it operates actively. The profitability of this idea lies primarily in building a long-term competitive advantage resulting from attention to every aspect related to the use of natural and human resources. Well-designed production processes result in less production waste. Reducing such

waste leads to less demand for raw materials, which - in turn - increases production efficiency ratios. An additional aspect is an awareness that the company guarantees future profitability to itself and others using fewer raw materials. Failing to implement the idea of sustainable production in enterprises may lead to a situation in which an efficiently operating and profitable enterprise will face the problem of the lack of raw materials for production in the future.

The study presents a practical model for implementing sustainable production strategies in manufacturing parts and components for agricultural transport means. The proposed approach minimises production costs and reduces post-production waste generation, achieving economic efficiency and environmental sustainability.

From a practical point of view, the findings demonstrate the potential benefits of adopting the suggested strategy. Manufacturers can realise significant cost savings and additional revenue streams by optimising raw material selection and implementing a product diversification approach to utilise post-production waste. The case study illustrates how these principles can be applied in a real-world manufacturing setting, providing valuable insights for practitioners in the agricultural transport sector.

From a scientific point of view, the research contributes to the existing literature on sustainable production management and resource optimisation. The study aligns with the growing emphasis on adopting environmentally conscious practices in manufacturing processes. The proposed model offers a practical framework for balancing economic objectives with environmental considerations, addressing the need for sustainable production strategies in industries with significant environmental impacts.

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Ethics approval and consent to participate

Not applicable.

Availability of data and material

The data are available on request.

Competing interests

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