Sustainability and sustainable development

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7.

SUSTAINABLE DEVELOPMENT IN PRODUCTION—OPERATIONS MANAGEMENT

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Abstract: Production-operation activity is one of the most important functions of modern enterprises. It requires the involvement of various types of resources, such as: raw materials, materials, machines, capital, information, energy, human factor and others, which are used in production processes. However, many problems arise in operational activity. They concern such aspects as: waste of resources or their wasteful use, mismanagement, excessive energy consumption, environmental pollution, exploitation of human potential, etc. It is also emphasized that these problems are reflected both in the growing costs of a company's activities and in climate change. However, more and more companies are becoming aware of these dangers and are implementing new products, new technologies and processes that use less raw materials and energy, being more environmentally-friendly. The purpose of implementing new solutions of production is to improve labour mobility, optimise the use of raw materials and resources, reduce costs, and to increase efficiency, productivity, etc.

Taking the impact of operating activities on the environment into account, the purpose of this chapter is to present selected production methods from their cognitive aspects, the assumptions of which are consistent with the issues of sustainable development. In particular, focus was placed on the zero-waste concept, which allows to eliminate waste in all links of the value chain. Lean manufacturing and six sigma, which help enterprises fight waste in their activity, as well as circular production related to the implementation of closed-loop production principles in practice, are discussed. In addition, the life-cycle product design and recycling, as well as green and environment-conscious manufacturing are presented. The first of them assumes that the possibility of recycling should be considered in the process of designing products and services. The second one should be identified with a modern and systemic way of managing enterprises, taking all environmental aspects into account by all departments.

Keywords: industry, production, production methods, sustainable production, waste, waste reduction.

7.1. Sustainability in operational management: theoretical background

Operational management (OM) is one of the most important functions of modern enterprises. It should be defined as "the design, control, operations, and improvement of the systems that create and deliver the firm's primary products and services" (Johnston, Chambers, Harland, Harrison, & Slack, 2002, p. 24). In a broader sense, it is understood as "a value- and quality-adding approach and philosophy to planning, organising and controlling organisational resources or input for optimum results in terms of efficiency and customer expectations. Operational management is viewed as a systems-oriented and highly integrative study of methods, tools, processes and techniques that coordinate "'the vital three' (people, systems and processes) with 'the central one' (physical and natural resources) in creating and adding value to meet organisational goals and customer requirements at an appropriate cost of acquisition, production, and distribution" (McFarlane, 2014, p. 16). It is related to the analysis of needs, opportunities, supplies and processing methods. In practice, it is often equated with the company's core activity, involving the conversion of production factors into a finished product or service. It further requires the involvement of various types of resources, such as: raw materials, materials, machinery, capital, information, energy and the human factor. The indicated elements constitute the company resources that should be properly managed. It is believed that their effective management is one of the most important challenges facing modern enterprises. The scale and scope of undertaken economic activities contribute to the consumption of huge amounts of resources, which is reflected in the climate change, mainly through the emission of greenhouse gases, liquid and solid wastewater. As a result, enterprises contribute to disruptions in sustainable development, the consequences of which will become apparent in the future (Corbett, 2009). The practices implemented nowadays demonstrate various problems related to operating activities. Those particularly important are waste of resources, mismanagement, excessive energy consumption, environmental pollution, exploitation of human potential, etc. In their operations, companies must also consider changes (both evolutionary and radical) in a hyper-competitive environment that is constantly changing. Globalisation, climate change, environmental degradation, resource depletion, technological progress, as well as increasing consumer awareness, force companies to implement strategies based on sustainable development. The identification and recognition of changes should be reflected in the set of activities, within which it is necessary to find, develop and use new, innovative methods and processes which, on the one hand, will eliminate the threat, and on the other, will allow

to create new value, based on a better, more economical and more rational use of resources.

The concept and significance of sustainable development (SD) were highlighted by the World Commission on the Environment and Development in 1987. It has been defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland, 1987, p. 8). According to Fredriksson and Persson (2011), such an approach covers social, ecological and economic problems. The economic aspect is focused on ensuring profitability in the short- and long-term. The social one refers to promoting social development and improving quality of life. The ecological problem aims at minimising the negative impact of human activities on the environment and protecting natural resources.

Gladwin, Kennelly and Krause (1995, p. 878–879), however, on the basis of a literature analysis, indicated that SD is described by 5 elements:

- inclusiveness, related to an expansive view of space, time and its components;
- connectivity, indicating that the problems of the modern world, including those economic, social and environmental, should be treated as interdependent and systemically related;
- equity, according to which the distribution of resources and property rights, both across generations and between generations, should be based on the principle of equity;
- prudence, which should be understood as striving towards maintaining the resilience of ecosystems, and to maintain the scale of human impact on the environment at a level that allows its regeneration and reconstruction;
- security, focused on people as well as their needs, and ensuring a safe and adequate quality of life, both for present and future generations.

Therefore, it can be emphasized that there are many interactions between operational management and sustainable development (Fredriksson & Persson, 2011). Both approaches are interested in technological, social, economic, environmental, and even legal and demographic issues. It is pointed out that the main issues considered by both approaches are reduction in the consumption of natural resources and the amount of waste in production processes, as well as increasing efficiency in terms of environmental and cost challenges. The interaction between operational management and environmental aspects is presented in Table 1.

In practice, it is emphasized that the implementation of the SD concept requires solving 34 issues (Mulder, 2006):

- significant reduction in resource consumption;
- elimination of non-renewable resource consumption cycles from production processes;
- focusing primarily on the use of resources and renewable energies.

Table 1. Intersections between OM and environmental concerns

Operations management	Aspects related to environmental concerns
Manufacturing perspective	Amount and type of waste as well as supportive materials; (Re-)use of heat, supportive materials, etc.; Location and use of plants; Use of management systems (e.g. EMAS, ISO14000, 14001, etc.) for pollution reduction and prevention.
Product development perspective	Amount of material used to realise functionality; Ratio of new/old material used; Material characteristics (toxicity, scarcity, etc.); Product architecture (modularisation); Use of life-cycle assessment for analysis.

Source: (Fredriksson & Persson, 2011, p. 238).

The implementation of the postulates given above, requires the involvement of both the society, state and local governmental bodies, enterprises, as well as other institutions. From the point of view of enterprises, it is therefore necessary to implement Sustainable Operations Management (SOM). This concept covers issues related to closed-loop chains, the green supply chain, green procurement, carbon footprinting of supply chains, life-cycle management, greening supply chains, green and reverse logistics, product and process development towards improving energy saving, efficiency of transport and other related areas (Gunasekaran & Irani, 2014, p. 801). The solution to the above problems requires the proper design of operations, organisation of resources, assessment of inter-organisational cooperation as well as analysis and comparison of asset productivity and labour efficiency. In the operations of enterprises, SOM becomes a key skill that effectively contributes to the development of sustainable supplies based on reliable relationships. It allows to improve the speed of response to customer needs, implement flexible production systems, reduce production costs, while protecting natural resources for future generations.

> Sustainable Operations Management can be defined as the operations strategies, tactics and techniques and operational policies to support both the economic and the environmental objectives and goals (Gunasekaran & Irani, 2014, p. 802).

Opresnik and Taisch (2015) indicate that companies wanting to include SD in their activities, must formulate an appropriate operational strategy. This can be defined as a "major decision about, and strategic management of: core competencies, capabilities and processes, technologies, resources and key tactical activities necessary in any supply network, in order to create and deliver products or services and the value demanded by a customer" (Bettley & Burnley, 2008; Opresnik

& Taisch, 2015, p. 534). The basis of this strategy comprise 2 challenges. The first one concerns the ability to connect a business with the environment; while the second one is its implementation. Within its framework, many activities should be undertaken, concerning both production, market and legal aspects. Such a strategy allows to reconfigure the business model. With its implementation, the new needs, challenges, benefits and perspectives emerge.

In an enterprise, SD in can be positioned at 2 levels: strategic and operational. In the first approach, this can be treated as a tactic supporting the main strategy; in the second one, it is a specific decision pattern influencing the current activity. It allows to identify operations that should be implemented, their importance in the production process and pattern of usage. Thus, sustainable development depends on individual operations which means that they have lasting impact on a specific part of the value chain.

Operational sustainability must be properly managed. This management consists of 2 distinct steps: strategy formulation and its implementation. Such an approach allows to examine the problem from 2 perspectives: prescriptive and normative. The first one answers the question as to "how things are done", while the second one—"how things should be done" (Opresnik & Taisch, 2015, p. 535). The process of formulating and implementing sustainable development in the operating activities is presented in Figure 1.

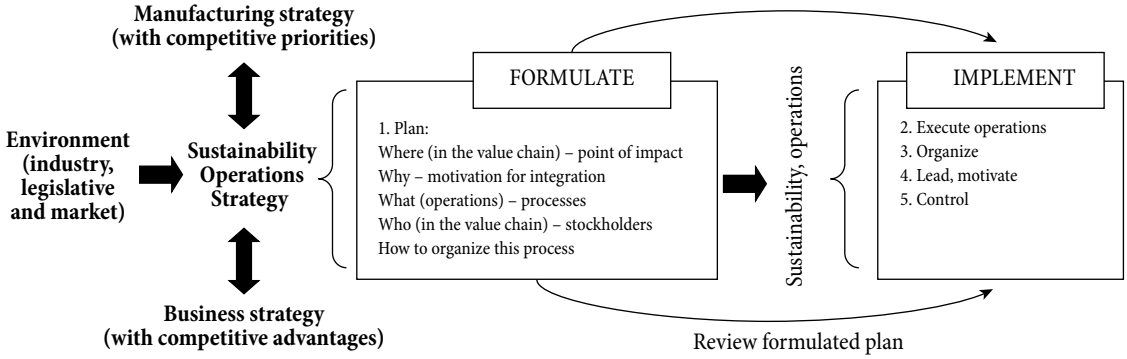

Figure 1. Sustainability in operations management

Source: (Opresnik & Taisch, 2015, p. 535).

Enterprises implementing the SD idea can use various methods and tools. These methods focus on aspects such as: production planning and control, organisation, next-generation production, processes, the use of supporting software, human factor, costs, product design, and ecological aspects. Their common feature is the pursuit of production based on limiting and preventing waste.

7.2. Zero-waste concept in operations management

With the processes of globalisation, technological progress and the growing purchasing power of individual societies, lifestyle changes. That current is based on saving and long-term use, and has radically transformed towards maximising consumption. Many products, such as household appliances and electronics, clothes, means of transport, and even some food products that were previously considered luxurious, are now used as basic goods (Crocker, 2013). There has been a dynamic development of consumerism, through which we should understand the moral doctrine viewing consumption as a way of achieving happiness, joy in life, the possibility of satisfying both physical and spiritual needs and desires (Lewicka-Strzałecka, 2003). It has also contributed to changes in the operational activities of enterprises which use composite and hazardous materials in their production processes. The waste generated during these processes is usually disposed of at landfills. These include electronic products, post-production scrap, chemicals, various types of polymers as well as animal and vegetable waste. Their number and multiformity simultaneously contribute to environmental pollution which is increasingly degraded. Factors influencing the shape, quantity and quality of waste are presented in Figure 2.

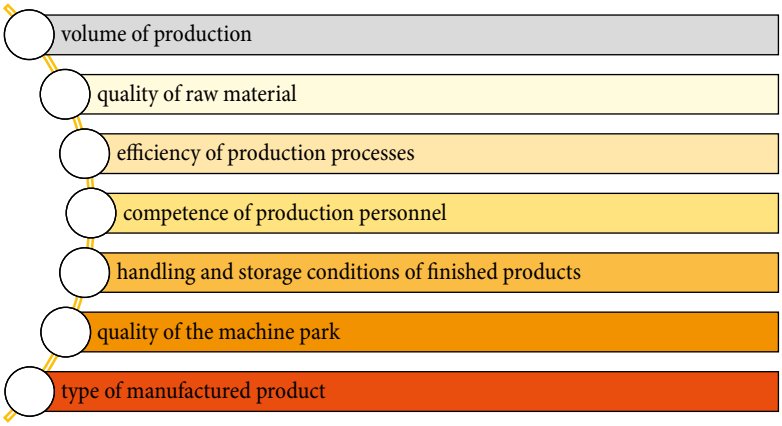

Figure 2. Factors influencing the shape, quantity and quality of waste

Source: Own research based on (Ohaegbunam, 2015).

Many companies recognise the problem and take various actions to completely eliminate waste in all links of the value chain. On the one hand, the aim is to limit the use of various raw and other materials, while on the other, to reuse waste, eliminate shortages in production process and other residues generated in production processes. Such an approach is related to the zero-waste concept, which can be most

simply defined as the minimisation of waste during production and consumption processes. This presents a challenge and a new goal of redesigning the entire system, related to the flow of resources and materials through the production process. This approach allows to maximise use, as it is assumed that the manufactured products can be reused, repaired, recycled or returned to the environment without any negative impact. The concept, thus defined, assumes a complete redesign of the industrial system in which the environment should no longer be perceived as an endless source of material supplies (Tennant-Wood, 2003, p. 47).

The zero-waste concept is, therefore, based on minimising the production of all kinds of waste, which directly affects the reduction of waste and environmental safety. The zero-waste concept indicates the need to sort waste, be responsible for its generation, implement storage fees depending on its quantity and the possibility of its management. There should also be a system of incentives and stimuli to implement the concept and, at the same time, a set of disincentives.

> Zero-waste is a goal that is ethical, economical, efficient and visionary, created to guide people in changing their lifestyles and practices to emulate sustainable natural cycles, where all discarded materials are designed to become resources for others to use. ZW means designing and managing products and processes to systematically avoid and eliminate the volume and toxicity of waste and materials, conserve and recover all resources, and not burn or bury them (ZWIA, 2009).

Apart from environmental aspects, entrepreneurs also pay attention to the costs related to waste. More and more manufacturers are beginning to recognise that waste generates costs in both entry and exit. In the first case, they are incurred at the time of purchasing raw materials and materials for production, in the second one, when discarding production residues. Therefore, the implementation of the zero-waste concept reduces production costs, improves financial results and enables better competitive position. Such an approach also helps to achieve goals related to the sustainable development (Zero-waste manufacturing, 2014).

The implementation of the zero-waste concept generates a significant number of problems. They are connected with the necessity to incur capital expenditures, reconfigure production processes and programmes, and change the mentality of staff. Traditionally, waste is easily identifiable as it consists mainly of physical substances that are easy to observe and measure. In the case of operation management, waste assumes a more abstract form that can be identified on the basis of labour efficiency analysis, i.e. comparing input (raw materials, labour, time, production process) with all identifiable effects, including finished products, inventory, waste, profits, etc. (Ohaegbunam, 2015). In practice, enterprises can use 2 methods, i.e. lean manufacturing and six-sigma, both of which facilitate the management of operations and enable the identification, elimination and improvement of waste quality (Zero-waste manufacturing, 2014).

7.3. Lean manufacturing and six-sigma in sustainable development

Analysing the operational activity of an enterprise, the following types of waste are of particular importance (Wiśniewska, 2005, p. 24):

- overproduction—understood as production exceeding and prior to establishing customer needs;
- waiting—i.e. idle production, in other words, hidden unproductivity caused by delayed delivery of materials or machine failure, planning errors, etc.;
- excessive processing—redoing activities or returning to activities that have already been done earlier at previous stages;
- excessive transport—carrying out transport activities above the expected level;
- excessive stocks—purchase over demand, storage of additional parts or products that the customer does not currently need. In other words, this problem is related to the capital frozen in articles or work completed and waiting for its turn;
- excessive traffic—all additional or too long-lasting activities needed to complete a task;
- errors and defects of products, or otherwise, production deficiencies;
- unused human potential, including wasting employee creativity.

The presented approach is primarily associated with production aspects, however, it should be noted that waste also affects the non-production sphere, associated with organisational, administrative, legal work, etc., as presented in Figure 3.

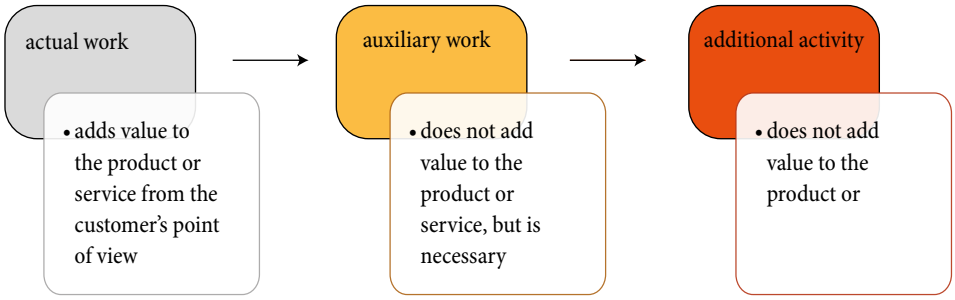

Figure 3. Work components

Source: Own research based on (Manos & Vincent, 2012).

Lean manufacturing and six-sigma are methods that help a company fight waste in its operations. The first one enables the identification and elimination of waste in the production process, while the second is focused on the reduction of defects in production, which directly improves the quality of products and services.

Lean manufacturing is defined as a specific concept and philosophy of production management, the aim of which is the maximum elimination of waste, unnecessary procedures, activities and processes, while ensuring maximum value for the customer (Halevi, 2001). The implementation of the method allows to scale up production with less consumption of materials, time and space, as well as better use of production capacity and manpower. It covers all activities related to the product, from its design to the transformation of raw materials, and materials into a finished product as well as the management of all information related to the organisation of procurement and distribution (Womack & Jones, 2003).

Lean manufacturing is an action strategy which is aimed towards efficient material flow and improved use of resources through elimination, reduction and control of waste (Modig & Åhlström, 2013).

The concept of sustainable development covers 3 problems: economic, social and ecological. They are influenced by production processes affecting both the social development and improvement of quality of life, the environment through its exploitation and pollution, as well as economic aspects, viewed through the prism of profitability. Therefore, the goal is to implement measures that will not have negative effects on any of the above aspects. This can be achieved through implementation of sustainable production, which is a specific combination of lean manufacturing and sustainable development, meaning "the creation of goods and services using processes and systems which are non-polluting, conserving of energy and natural resources, economically viable, safe and healthful for employees, communities and consumers, and socially and creatively rewarding for all working people" (Lowell Center for Sustainable Production, 1998).

Thus, it can be emphasized that lean manufacturing is closely related to sustainable development and contributes to its strengthening from the various perspectives (Järvenpää & Lanz, 2020). In particular, there is reduction in the amount of generated waste, as well as the desire to use materials and raw materials used for the production processes in a closed loop. The assumptions of the concept can also be used as guidelines in the formulation of manufacturing and sustainable ecological strategies. Järvenpää and Lanz (2020), analysing the relationship between lean management and sustainable development, indicate that reducing the amount of waste generated in the production processes affects the economic and social sustainability. Appropriate organisation of the workplace, improvement of safety, tidiness and order, as well as involvement in improvement activities positively, influence the perception of a company by various stakeholders. Such activities are directly reflected in the employees' approach to work, who show greater commitment and care for the assets entrusted to them. As a result, the company can offer better-quality products while reducing costs (see Figure 4).

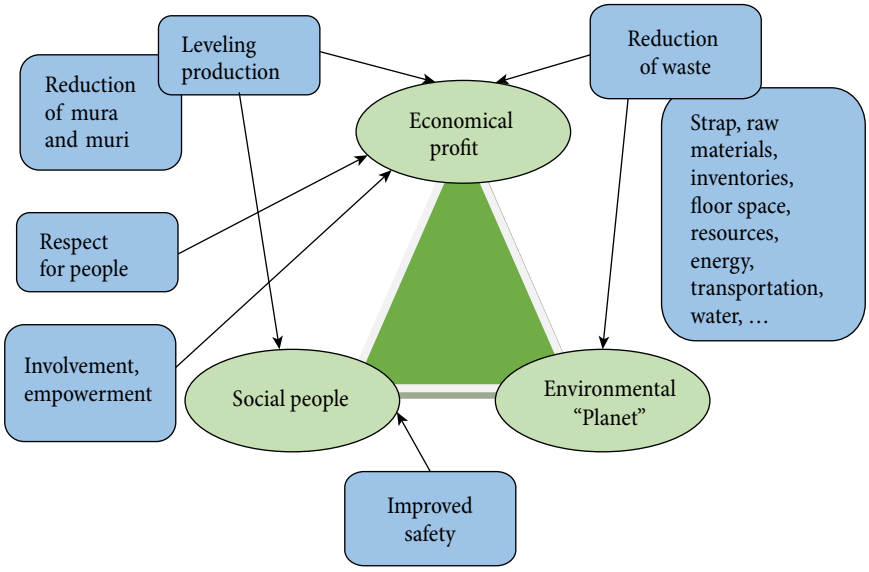

Figure 4. Support of lean to sustainable development

Source: (Järvenpää & Lanz, 2020, p. 7).

The relationships between lean manufacturing and sustainable development include correlation, overlapping areas, difference, integration and classification based on sustainability dimensions. This relation is reflected both in the improvement of efficiency as well as in environmental and economic aspects (Hartinia & Ciptomulyonob, 2015).

Six-sigma is a modern management method based on continuous data acquisition and analysis in order to achieve excellent quality. The essence of the method is to identify errors before they occur. This involves continuous monitoring and control of all processes and procedures, which allows to eliminate and prevent various types of discrepancies between the expected product and its actual image. In practice, the implementation of the concept is associated with a permanent reduction in costs that arise when the quality deviates from the original assumptions. The assumptions of the concept fit directly into the idea of sustainable development, especially in terms of reducing waste, increasing efficiency and improving the efficiency of an organisation and all procedures, processes, operations, etc. The main advantages of six-sigma include elimination of variability, ensuring customer satisfaction, reducing the duration of production cycles, reduction in costs related to the correction of errors, repairs, production shortages, as well as improvement of the company's competitive position. These effects can be achieved by defining, measuring, analysing, improving and controlling (DMAIC) all structures of a given organisation (this is shown in Figure 5). This, in turn, enables effective

management of the production programme, transfer, measurement systems, and further allows risk assessment and designing processes enabling environmental sustainability (Kadry, 2013).

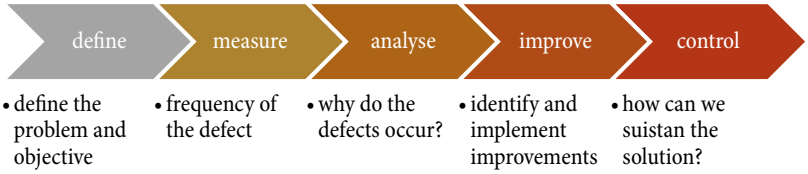

Figure 5. Methods of six-sigma

Source: Own research.

It is emphasized that by implementing the assumptions of the six-sigma concept into practice, enterprises achieve better environmental results. They can focus on reducing the amount of waste, and they also use ecological management tools, which contributes to "green thinking". Linking six-sigma techniques and tools to sustainable development should contribute to (Magraner, 2019):

- maintaining a clean and organised work environment;
- reducing the consumption of input needed to perform operational tasks and motivating the staff to correctly identify and remove production waste;
- optimising the use of raw materials and materials, and preventing the formation of unnecessary, excessive and unjustified inventories;
- improving the operation of the machine park as well as energy and material efficiency;
- appropriate waste management;
- paying attention to environmental problems and engaging in solving them;
- implementing and using new tools to understand and solve problems related to sustainable development;
- identifying and reducing defects, both in production processes and in the final product, which reduces environmental waste;
- organising appropriate working conditions, ensuring safety, and thus reducing the number of accidents at work.

From an ecological point of view, six-sigma influences a more efficient use of resources, reduces waste and pollution, and thus, decreases negative impact on the environment. In economic terms, it can ensure the loyalty of buyers, a reliable market, increase profits and improve the reliability of the machine park, processes, procedures, etc.

It should be emphasized that specific solutions related to both lean manufacturing and six-sigma depend on the sector, type of enterprise, production techniques used, machine park, workforce, applied raw materials, etc. Heavy industry

enterprises, such as shipyards, mines or steel mills, assume different approaches to the problem of sustainable development than companies focusing on the production of consumer goods, with modern, innovative equipment.

7.4. Circular production

By implementing goals related to sustainable development, the enterprises can apply the principles of closed-loop production in their operating activities. This method completely changes the way an economic entity functions, its philosophy, perspectives, and the way it is perceived by the environment. This contributes to the creation of a completely new model of resource management, dealing with its lack of value creation as well as a policy in the field of procurement, safe-keeping and storage of materials. It is also reflected in the principles of employing, motivating and remunerating employees, especially those directly in production.

Circular production is identified with a production and consumption model in which raw materials, materials, semi-finished products as well as other components used in production processes and finished products remain in circulation as long as possible (Geissdoerfer, Pieroni, Pigosso, & Soufani, 2020). For this purpose, many activities are used, including: joint using, sharing, leasing, repairing, reusing, refurbishing, reconditioning, etc. If certain resources and products cannot be used any further, they should be recycled to recover raw materials and be reprocessed. Therefore, it may be emphasized that raw materials, materials and various components used in production processes lose their value to a very small extent, and over a long time 'horizon'. By implementing the ideas of closed-loop production, renewable energy sources are also used. Thus, circular production contributes to the development of sustainable production and consumption. Its main advantages are reduction in various types of waste and energy saving, which is reflected in the decrease in air, water and land pollution. This approach is the complete opposite of the traditional, linear economic model, based on the principle of "take-make-use-dispose" (Andrews, 2015). Circular production is considered to be comprised on the foundation of 3 components: closed cycles, renewable energy and systems thinking (Korhonena, Nuurb, Feldmannb, & Birkie, 2018).

The material circulation of circular production is based on the principle of an ecosystem where there is no residue, everything is biodegradable. This means that in production processes, all waste, whether solid, liquid or gaseous, can be reused, e.g. in the production of a new product. Toxic substances and materials generated in the production process should be eliminated or neutralised (the process of circular economy is shown in Figure 6). The basic principle of closed cycles is the receipt of manufactured products by their producers from their users after the period of use, and then, their renewal or processing with maximum use of components. It

can therefore be emphasized that an extremely important issue is the appropriate design of a product, the components which should, on the one hand, be of high quality, and on the other, be easily recyclable (Korhonena et al., 2018).

In today's world, energy is an extremely significant problem, especially that generated from traditional raw materials such as lignite and hard coal, oil or gas. Hence, a change that will contribute to the use of renewable energy sources is necessary, i.e. energy that does not harm the environment and does not run out quickly. This issue is greatly significant for circular companies, as energy cannot be recycled and is not subject to a recurring cycle. In practice, companies can use sun, water, wind, geothermal energy and biofuels.

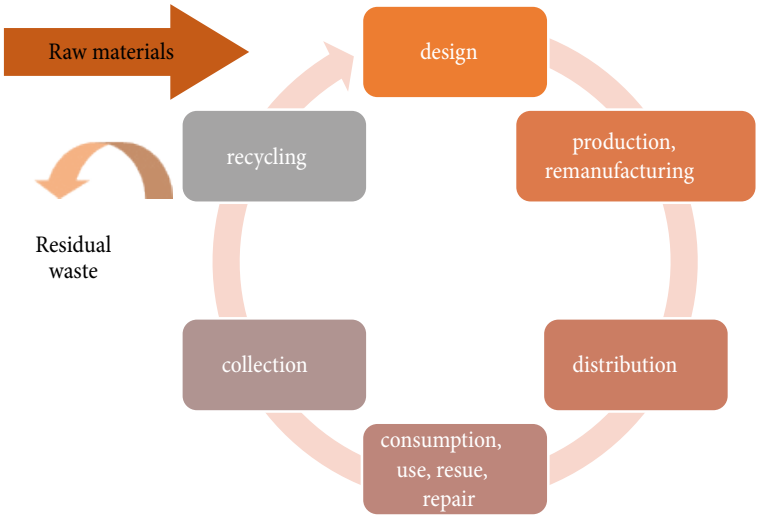

Figure 6. Processes of circular economy

Source: Own research.

The final element of the circular economy is systems thinking, which should be understood as "discovering patterns of connections and dependencies among seemingly unrelated beings (events, processes, things, beings). It is often associated with descriptions such as holistic, deep or process thinking" (Zych, 2013, p. 16). Today, there are no closed-loop enterprises. Achieving goals requires collaboration which means that each enterprise is part of a larger network. The actions of each participant influence the remaining actors. When implementing the postulates of a closed economy, one should look for and cooperate with such partners who follow similar patterns of behaviour, rules of conduct, or are characterised by a pro-environmental organizational culture.

The implementation of closed production principles brings many benefits, both for the company, society and the entire economy. It allows to reduce the use of

natural resources, which further contributes to cost saving, generation of growth and optimisation of employment. It also influences the identification of new opportunities, stimulates innovation and improves competitive position. As a result, it has a positive effect on the environment, both from the point of view of climate change and its pollution (*Circular economy: definition, importance and benefits*, 2020).

7.5. Life-cycle product design and recycling

The production method known as life-cycle product design and recycling, also fits perfectly into the issues of sustainable development. The concept assumes that the recycling options should be considered in the process of designing products and services. This approach assumes that already at the conceptual stage, it is ensured that environmental pollution is avoided in the future and that benefits are obtained after final withdrawal of the product from the market (Halevi, 2001). A product, the design of which is based on life-cycle, contributes to maximum use of raw materials and materials. At the same time, it leads to the minimisation of economic, social and environmental efforts during the products' life-cycle (Zbicinski, Stavenuiter, Kozlowska, van de Coevering, 2006).

Life-cycle product design and recycling is defined as the environmentally--friendly process of designing a product or service, taking all life phases into account, from designing, sourcing and using raw materials, to supply, production and distribution, and ending with the use of materials and components after product withdrawal from the market (Summary Final Report, 1995). In the design process, particular attention should be paid to components and materials that can be used in the future. Not all of them will find their application, especially in the case of traditional raw materials that have already been depleted. Moreover, technical progress and technological development, especially regarding recycling and processing of secondary raw materials, should be regarded. It may turn out that today's difficulties with recovery will not be of great importance in the perspective of a few or several years. Attention should also be paid to the future environmental, economic, social and legal conditions. When designing a product or service, all actors directly or indirectly related to the product should be considered, including contractors, subcontractors and users.

It is additionally emphasized that when designing a new product, there are many different types of problems. They concern both the complexity of products and services, the variety of raw materials used, various types of components with a harmful effect on the environment, and partners who will perform specific work and tasks. Cooperation with subcontractors who will not always take into account or be able to meet the requirements specified in the Project, is particularly important. Production capacity and quality of production potential are starting to become

problematic. An significant issue is also the logistics related to product collection and recycling, especially if they were intended for a dispersed consumer market. In practice, there is no system of stimuli or incentives that would persuade users to return worn and used products, especially those of small size and cost, that can be simply thrown away. In the Summary Final Report (1995), it has been indicated that life-cycle product design and recycling are associated with several complex problems:

- reduction in product quality due to the use of environmentally-friendly materials with worse parameters, which contributes to shortening service life;
- recycled materials, reused in production processes, are often characterised by worse quality parameters, such as durability or resistance to external factors, which shortens their useful life span;
- recycling recovered and raw materials requires the involvement of additional funds, including energy, making it uneconomical and unprofitable in some cases;
- various types of components, solutions or materials with a harmful effect on the environment are often used in the recycling processes, which raises a number of ecologically-related doubts;
- there is a possibility of environmental pollution with unknown and harmful substances that have been added to the product by their users, especially industrial ones;
- in some cases, there is no interest in recycling from subcontractors, users or companies dealing with material recovery (e.g. due to low profitability).

Analysing the indicated threats, particular attention should be paid to companies that deal with recycling and disassembly. They must be equipped with a special technology that, on the one hand, will enable the recovery and processing of raw materials, and on the other, will meet qualitative and quantitative requirements, ensuring trouble-free operation, without negative impact on the environment. The appropriate co-operation between the manufacturer, user and recycling company is therefore required as well as compatible reciprocal information exchange.

7.6. Green and environment-conscious manufacturing

Green and environmentally conscious manufacturing comprise another group of methods used in the operational activities of enterprises that enable the implementation of the sustainable development idea.

Green manufacturing (GM) should be equated with a modern and systemic way of managing an organisation in which all cells are managed with regard to environmental aspects. The key elements of GM are presented in Figure 7. From a production point of view, the term is defined as "practices that produce environmentally-friendly products and minimize the impact on the environment

through green production, green research and development, and green marketing" (Peng & Lin, 2008). Loknath and Azeem (2017) indicate that the above terms should additionally be supplemented with continuous improvement, sustainable development and innovation. According to the authors, GM is also associated with environmental management and sustainable corporate development because apart from reducing waste and pollution, the ideas of green management should also be taken into account.

> Green manufacturing is the organisation-wide process of applying innovation to achieve sustainability, waste reduction, social responsibility, and a competitive advantage via continuous learning as well as development, and by embracing environmental goals and strategies that are fully integrated into the goals and strategies of the organisation (Loknath & Azeem 2017; Haden, Oyler, & Humphreys, 2009).

Activities undertaken within the GM concept consist of 4 phases: those conceptual, preparatory, production-related and final (Skibinska & Kott, 2015). In the first phase, analysis of the company's environmental impact should be conducted, and then, appropriate systems should be implemented, in which the results of the analysis are included. The second one defines GM goals and criteria, and develops new methods. Particular attention should be paid to the division of tasks, responsibilities, controlling and the incentive system. In the production phase, so-called green control is conducted, allowing to identify and assess the amount of generated waste and pollution. The results of control are taken into account during the procedure in which the plan for the optimal use of energy and resources should be presented. In the final phase, the principles and rules for exploiting the organisation's potential with lower energy and resource consumption should be developed (Skibińska & Kott, 2015).

The implementation of the GM concept brings many benefits to the company, in particular, it reduces the cost of raw materials. A company recycling materials it had previously purchased does not have to incur costs for their repeated purchase. Moreover, GM influences the increase in production capacity, work efficiency and better use of production potential, while being cost-effective with regard to environmental expenses and ensuring work safety. By using less hazardous materials, savings are made on their transport and disposal (Askew & Desai, 2018).

Environmentally conscious manufacturing (ECM) is "the deliberate attempt to reduce the ecological impact of industrial activity without sacrificing quality, cost, reliability, performance, or energy utilization efficiency. The principle of environmentally conscious manufacturing is to adopt those processes that reduce the harmful environmental impacts of manufacturing, including minimization of hazardous waste and emissions, reduction of energy consumption, improvement of materials utilization efficiency, and enhancement of operational safety" (Halevi, 2001, p. 150).

Figure 7. Key elements of green manufacturing

Source: (Aydin, Yaldiz, & Buyuksahin, 2017).

Halevi (2001, p. 150) points out that more and more enterprises are becoming "ecologically aware", and when implementing new products, technologies or processes, they take such aspects as saving energy, water and natural resources into account.

> Environmentally conscious manufacturing (ECM) is concerned with developing methods for manufacturing new products, from conceptual design to final delivery and ultimately, to end-of-life (EOL) disposal, so that environmental standards and requirements are satisfied (Gungor & Gupta, 1999, p. 812).

The main assumption of the ECM concept is to minimise harmful impact on the environment throughout the entire production cycle and entire product life-cycle, which should ultimately contribute to the more efficient use of resources. Its scope covers all functions related to the production of a product or service, from planning and procurement, to the development and organisation of production processes, ending with packaging, transport and disposal. It is assumed that each process will eliminate or significantly reduce waste emission and production shortages. In addition, operational safety should be improved, and the manufactured product,

after its useful life, can be recycled or regenerated for reuse (Yusuff, Vahabzadeh, & Panjehfouladgaran, 2012). All activities are undertaken within the context of reducing or minimising the amount of solid, liquid and gaseous pollutants. Therefore, the stage of designing a product, process or technology is particularly important, as during which, the potential and capabilities of the enterprise, as well as internal and external conditions, should be taken into account. In particular, attention should be paid to (Halevi, 2001, p. 151):

- the project of product disassembly and disposal after its useful life, reducing the amount of waste and obtaining recycled material;
- pro-ecological production—thanks to the use of newer and more environmentally-friendly technologies, production processes and efficiency are improved, while production capacity increases, etc.;
- comprehensive quality and environmental management, which means that one should strive for harmony between the company and the environment, and not treat the latter as only a supply of resources;
- industrial ecosystems which are interconnected companies with a similar pro-ecological approach, thanks to which waste generated in one enterprise can be used as a raw material for a partner;
- technology, through the prism of its impact on the social, economic and ecological environment, with particular emphasis on the possibility of recycling the materials used.

In order to take the above postulates into account, a company must implement an appropriate design process. In practice, the life-cycle assessment (LCA) technique is used. It is a method that focuses on all environmental aspects of the production, including use, disposal and potential reuse (Halevi, 2001). LCA analysis considers all phases of the product life-cycle, from raw material acquisition, to production, distribution and use, ending in disposal. Therefore, it enables reporting the potentially negative environmental impact at each stage of the product or service supply chain.

Questions / tasks

1. Please discuss the narrow and broad meaning of operational management?
2. What are the problems related to the company's operational activity?
3. What is the relationship between operational management and sustainable development?
4. Explain the concept of Sustainable Operations Management.
5. Discuss the stages of managing sustainable development in operational activities.
6. What is consumerism?
7. What factors influence waste in production processes?

8. Explain the assumptions of the zero-waste concept in operating activities.
9. What is waste and what types of waste in an enterprise do you know?
10. What is the difference between lean manufacturing and six-sigma?
11. Discuss the assumptions of lean manufacturing.
12. Discuss the assumptions of six-sigma.
13. What are the effects of linking six sigma principles to sustainable development?
14. What is circular production?
15. Discuss the process of circular economy.
16. What are the benefits of a company operating according to the circular-economy concept?
17. What are the assumptions of life-cycle product design and recycling?
18. What are the problems related to life-cycle product design and recycling?
19. What is green manufacturing?
20. What is environment-conscious manufacturing?
21. What phases can be identified in green manufacturing?

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