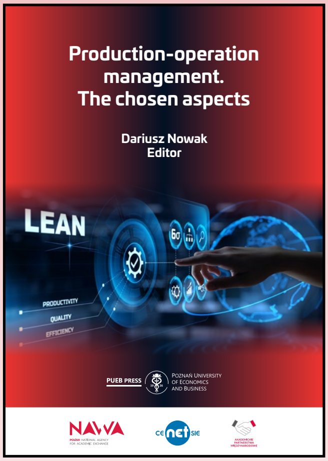

Production-operation management. The chosen aspects

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5.

MODERN METHODS USED IN PRODUCTION-OPERATIONS MANAGEMENT

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Abstract: Climate change, resource depletion, technical progress, growing consumer awareness and changing requirements causes companies to look for new production methods. They may concern various areas of the company's activity, starting from product design, procurement organization, optimization of production processes, control of manufactured products and services, through improvement of work organization and reduction of production costs, and ending with the implementation of modern solutions based on digital technologies. The purpose of implementing new production methods is to improve labour mobility, optimization of the use of raw materials and resources, costs reduction, increase efficiency, productivity, etc. In the literature, there are many different types of methods that can be used by modern enterprises. It is practically impossible to present all methods in this study. The authors focused on the presentation of selected methods, which are characterized on the one hand by innovation and, on the other hand, by the possibility of implementation.

Particular attention should be paid to methods focused on environmental aspects. This group presents basic information on environment-conscious manufacturing (ECM), life-cycle assessment (LCA) and waste management and recycling. These methods allow to implement the concept of sustainable development and are directly related to the 17 goals set out in the 2030 Agenda for Sustainable Development and adopted by UN member states. In the group of methods related to next generation production management, the focus was on Matrix shop floor control and cooperative manufacturing. Of particular importance is cooperative management, because cooperation in practice is considered as a specific resource and one of the most important factors of a competitive position. The next group of methods concerned production planning and control. Drum Buffer Rope (DBR) and theory of constraints (TOC) were discussed as part of it. From the company's point of view, methods related to manufacturing processes are very important, including group technology (GT) and cellular manufacturing (CM). Another group focused on commercial aspects, including demand chain management (DCM) and competitive intelligence (CI). The chapter also presents methods related to auxiliary software support, advanced organizational manufacturing and focused on product design. In the first case, Electronic Data Interchange (EDI) was discussed, in the second, virtual enterprises (VE) and World Class Manufacturing (WCM) were presented, and in the third, the assumptions concerning the Quality Function Deployment (QFD) and House of Quality (HOQ) method were shown. Additionally, Statistical Process Control (SPC) and Computer-Aided Process Planning (CAPP) are discussed within the framework of methods focused on cost and quality manufacturing.

Keywords: control, cooperation, production competence, production design and planning, production methods, quality and production costs, sustainable production.

5.1. Introduction

By implementing compiled and complex goals, enterprises can use various methods, techniques and tools in their core activities. Their choice depends on the industry branch, type of production and type of product, size of the enterprise, market in which the entity operates, etc. They can be divided according to various criteria. The basic criterion divides them into traditional and modern. The first of them are well known in practice and often used, while the second ones are less obvious, focus on specific conditions and problems related to a specific industrial activity. When analysing various criteria for the classification of production methods, it is worth paying attention to an interesting division proposed by Halevi (2001, pp. 20–23). The author divides methods used in production activities into 12 groups:

1. Focus on manufacturing hardware.
2. Focus on auxiliary software support (Electronic Data Interchange).
3. Focus on production planning and control (theory of constraints, Drum Buffer Rope).
4. Focus on next generation production management (Shop Floor Control, cooperative manufacturing).
5. Focus on processing manufacturing methods (group technology, cellular manufacturing).
6. Focus on commercial aspects (demand chain management, competitive intelligence).
7. Focus on organization,
8. Focus on advanced organizational manufacturing methods (virtual enterprise, World Class Manufacturing).
9. Focus on product design methods (Quality Function Deployment, House of Quality).

10. Focus on human factors in manufacturing.
11. Focus on environmental manufacturing methods (environment-conscious manufacturing, life-cycle assessment, waste management and recycling).
12. Focus on cost and quality manufacturing methods (Statistical Process Control, Computer-Aided Process Planning).

The methods discussed in this chapter are given in brackets.

In each of the indicated groups, Halevi (2001, p. 16), describes several detailed methods, indicating their type which is characterized by:

- technological solution, requires hardware resources,
- software solution, requires computer,
- management—methodical directions for organization and managing,
- philosophical—modern management methods,
- auxiliary programs to the methods that support the objective of company.

Some of the indicated methods are used in practice, some of them, however, have a typical theoretical nature and are difficult to implement. A brief description of the selected methods is presented below.

5.2. Shop Floor Control

In the simplest terms, a production hall can be defined as a building with a large area intended for production purposes. Various manufacturing processes take place there, including the processing of raw materials and materials as well as processing, bonding, cutting, forging, cutting, milling, assembly, packaging, etc., using automated systems or workers working on machines or devices. The production hall includes (Shop Floor Management, 2017):

- machines, equipment and tools determined by the sector in which the enterprise operates, the type of production and also the type of technology,
- materials, raw materials as well as other types of resources, such as parts, details, semi-finished products from cooperation, subject to the conversion process,
- information technology related to control systems, production execution, management of production operations, controlling, quality, etc.,
- quality control, i.e. activities aimed at checking whether the manufactured product corresponds to its characteristics,
- storeroom in which both production stocks and spare parts, auxiliary materials, utility goods, etc., used in the company's operational activities are stored,
- personnel consisting of direct production workers as well as technical and engineering workers who supervise the processes taking place in the production hall.

The production hall management concept is directly related to production management. It is based on the multi-agent paradigm and concerns the design and implementation of systems related to process control that take place in the production hall. The basic opinion of the concept is to support discrete processes related to workshop manufacturing (Colak, 2004). It includes methods and a hierarchy system for priority tasks, supervising and reporting production orders, and preparing schedules. In addition, the state of production stocks, extensive and intensive use of production potential, labour and procedures for planning, organizing, scheduling and cost calculation related to the functioning of the production hall, are subject to special supervision.

Shop Floor Control (SFC) is a system of computers and/or controllers tools used to schedule, dispatch and track the progress of work orders through manufacturing based on defined routings. SFCs typically calculate work in process based on a percentage of completion for each order and operation that are useful in inventory valuations and materials planning (Gartner Glossary).

According to Halevi (2001), the basis of the philosophy of the production hall management concept is the flexibility of all parameters of the production process. Each of them can be properly adapted to the current needs and requirements which should contribute to the improvement of the productivity of the entire system. A machine, person, place, process, and even its course can be relocated. The only elements that are stable are the products manufactured and the resources used to produce them. The shop floor control integrates dispersed elements related to the organization of the production process into one coherent system that is subject to continuous monitoring and analysis. In practice, such an approach should contribute to an increase in efficiency, improved productivity and quality of production (Materna, Hinrichsen, Adrian, & Schulz, 2019). The implementation of the concept also enables the correct planning of resources, taking into account the inventories at the disposal of the company and their correct valuation.

Thanks to the use of shop floor control, the company is able to identify weak links, bottlenecks and other threats related to all aspects of a specific production environment. In addition, it is indicated that the purposes related to the management of the production hall include (Shop Floor Management, 2017):

- routing movement of material on shop floor appropriately,
- sequencing the procedures and processes taking place on shop floor,
- scheduling of workforce, resources and operations,
- finding deviation from standard procedures and processes,
- identifying loopholes in shop floor communication.

The implementation of shop floor control consisting in the permanent organization, piloting and control of production processes in the production halls should bring many benefits. They concern both the increase in the efficiency of using the production potential, material savings and the elimination of production errors or unproductive downtime. In particular, the following profits can be indicated (Shop Floor Management, 2017):

- increased operational efficiency through standardization of operations,
- reduction in occurrence of errors in work,
- revealing of loopholes in production or processes,
- increases productivity of the staff,
- positive impact on the revenue of a manufacturing business.

Figure 5.1. The shop floor control integration system

Source: Own study based on (Shop Floor Control, 1997, p. 21).

The indicated benefits are achievable only when correct data is provided to the system. Only the right information and its proper processing can contribute to the improvement of the productivity of all elements constituting the equipment of the production hall.

5.3. Cooperative manufacturing

Nowadays, no enterprise is able to function independently. Each of them, regardless of its structure, manufactured product, provided service or possessed resources, in order to achieve its complicated and complex goals, must actively seek, establish and maintain relationships with other enterprises. These relationships build a system of mutual dependencies and connections, within which cooperation develops in the production of materials, parts, elements, assemblies, subassemblies, or the provision of specific production services.

The cooperation can be interpreted through the prism of various approaches (Cittolin, 2018, p. 29):

- Sociology cooperation: a form of interaction in which individuals strive to achieve a collective and common goal, being essential in the constitution of most social groups.
- Economic cooperation: a cultural construction that is based on social interaction, where goals are common, actions are shared and benefits distributed with balance throughout the system.

According to Halevi (2001, p. 111), the basis of cooperative production is the belief "that it is difficult and expensive to anticipate disturbances and prepare meaningful programmed responses to a specific situation". Only joint action allows to overcome emerging difficulties, related to technological processes, resource availability, workforce, operational activity as well as innovative development.

Figure 5.2. Economic, sociological and ecological approach to cooperation

Source: Own study based on (Random House, 1993, p. 446).

In practice, the production process is divided into many sub-processes which are carried out by different companies (Hao, Shen, & Wang, 2005). Entrepreneurs also know their limited production capacities, they are also aware that some processes can be performed more effectively, efficiently and more efficaciously using external sources. It can therefore be emphasized that the increase in the scale of tasks entrusted to co-operators is related to the long-term strategy of enterprises. It consists in limiting own tasks in favour of those that are the most effective from the point of view of the competences held and that can bring the greatest profit. Limiting the number of own tasks in enterprises dealing with the production of final products contributes to the simplification of their structure, shortening of production cycles as well as faster offering of the product on the market with lower margins. Enterprises must therefore cooperate with other market participants. This cooperation may be simple, based on the so-called pure transactions or multi-dimensional, in which all aspects of the cooperation are specified. In the first case, the subject of the transaction are standard, generally available parts and elements, the so-called industrial standardized materials, in the second one, the basis for the agreement is a product or service, manufactured according to the detailed specification of the recipient (passive co-operator), its schedule, quality, technological and cost requirements.

In practice, it is believed that each entity carrying out specific production operations related to the creation of a product, increases its value which affects the total value of the products. The entity brings its key competences to the joint venture which should complement each other, permeate and integrate. In this way, relationships of different nature, scope and strength of influence are created between the cooperating companies which guarantee long-term cooperation and contribute to taking up new challenges, setting new goals and tasks, and thus contribute to innovative activities. Thus, networks of cooperating enterprises are formed, legally and organisationally independent which create a new structure of business and operation.

The principle of reciprocity is defined as the desire and willingness to be polite and helpful to those whose behavior and action is based on courtesy, kindness and helpfulness, and to harm those who, through their actions, signal hostility and aversion (Keser & van Winden, 2000, p. 36).

In cooperative production, a very important problem is the selection of the right partners who will participate in the joint production process. The selected partners must have the appropriate skills, experience, competences, qualifications as well as be innovative and creative. An important problem is also the appropriate technology which must be compatible with the technology of a passive co-operator and other resources, including human resources.

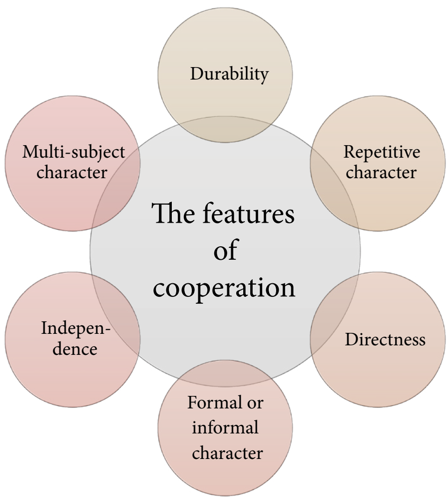

Figure 5.3. The features of cooperation

Source: Own study.

The basic condition of cooperative production is achieving benefits that outweigh the costs. These benefits essentially depend on the quality of the input made by other companies as well as their willingness to share that input with others. It can therefore be emphasized that the fundamental norm of cooperation is the principle of reciprocity (Koch, Kautonen, & Grunhagen 2006, p. 63). It says that in many social situations we pay back what we received from others. The principle of reciprocity emphasizes partnership and the willingness of entities to accept short-term difficulties, while expecting that other entities will show a similar attitude. In this context, there should be emphasized the proactive aspect of cooperation as opposed to the imperative aspect that occurs in interdependent activities. As a consequence, companies promote teamwork, jointly set goals and reach a consensus of action (Deepen, Goldsby, Knemeyer, & Wallenburg, 2008, p. 78). The principle of reciprocity has two important implications: the first one is related to trust which allows sharing experience and creating relationships, the second one involves specific investments that create a certain level of dependence between cooperating entities (Zook and Allen 2005, p. 96).

Cooperation may relate to various areas of business activity. Particularly important are (Nowak, 2012):

- research and development and technology transfer,
- preparation of production,
- designing, organizing, supervising, monitoring,
- production and assembly—manufacturing of specific elements, parts, subassemblies, assemblies,
- production service,
- services such as: transport and forwarding, loading, storage, unloading, maintenance, repairs,
- joint operation of fixed assets,
- joint investments,
- management and others.

Cooperation may be narrow, concerning one area or its fragment, or comprehensive, consisting in complete, large-scale cooperation.

5.4. Environment-conscious manufacturing (ECM) and life-cycle assessment (LCA)

The condition of the natural environment, both in Poland and in the world, is constantly deteriorating. The basis of degradation is primarily economic development related to humans striving to improve living conditions. Urbanization, expansion of infrastructure, devastating extraction of raw materials as well as consumerism contribute to the pollution of air, water and land. The area of agricultural and forest areas is decreasing, the topography is distorted, water reservoirs are drying up, vegetation and individual species of animals are dying out, pollution increases which in turn leads to climate change. The processes related to the devastation of the environment have particularly intensified in recent years, especially in countries that are striving for rapid industrialization. The production activity contributes to the rapid degradation of the environment. Technical progress, implementation of new technologies, short product life cycles consume more and more resources, and at the same time impede sustainable growth.

The issues of the natural environment and sustainable development are widely discussed both on the national and international forum. On September 2015, the 2030 Agenda for Sustainable Development was adopted by all United Nations Member States. The agenda provides a shared blueprint for peace and prosperity for people and the planet, now and into the future. The document defines 17 Sustainable Development Goals and 169 targets. They concern achievements in 5 areas—the so-called 5 × P: people, planet, prosperity, peace, partnership. Goals cover a wide range of challenges such as: no poverty, zero hunger, good health and well-being, quality education, gender equality, clean water and sanitation, affordable and clean energy, decent work and economic growth, industry, innovation and infrastructure, reduced inequalities, sustainable cities and communities, responsible consumption and production, climate action, life before water, life on land, peace, justice and strong institutions, partnerships for the goals (United Nations).

However, with the increase of pollutants emitted to the environment, the awareness of enterprises about the importance of sustainable development grows. More and more companies are making changes in production processes, focusing on ecological, socially responsible production, aimed at caring for the world around us. One of the methods that has become more and more popular in recent years is environment-conscious manufacturing (ECM). The main assumption of the concept is to minimize the harmful impact on the environment throughout the entire production cycle and the entire product life cycle which should ultimately contribute to a more efficient use of resources. Its scope covers all functions related to the production of a product or service, from planning and procurement, through the development and organization of production processes, to packaging, transport and disposal. It is assumed that each process will eliminate or significantly reduce waste emissions 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).

The implementation of the ECM concept should therefore be reflected in three aspects:

- reduction or waste minimization which will prevent pollution,
- recycling strategy which involves the need to redesign the product and implement a new production technology,
- remanufacturing strategy, i.e. the ability to recover the value of a product or components.

Environment-conscious manufacturing (ECM) is the deliberate attempt to reduce the ecological impacts of industrial activity without sacrificing quality, cost, reliability, performance, or energy utilization efficiency. The principle of environment-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).

The above activities should be reflected in all production processes, production technology, resource management as well as activities related to materials and finished products. As a result, the consumption of energy and resources used in production should decrease which in turn will contribute to the reduction of pollution and protection of the natural environment.

The basic assumption of the ECM concept is a properly designed and manufactured product, with the assumption of minimal environmental impact. In the design process, there can be used the life-cycle assessment (LCA) technique. It is a method that focuses on all environmental aspects of production, including use, disposal and eventual reuse (Halevi, 2001).

LCA enables the reporting of potentially negative environmental impacts at each stage of the supply chain of products or services. Identification of threats allows to develop a set of remedial and corrective actions. The purpose of these activities is to repair, improve or replace specific environmental elements or their functions, if they have become damaged. Moreover, the strategy makes it possible to identify those raw materials and materials that have a harmful effect on nature, and to choose alternatives that are renewable or recyclable. The LCA analysis takes into account all phases of a product's life, from raw material acquisition, through production, distribution and use, to disposal (Figure 5.4).

The implementation of LCA in the core business of the enterprise can bring a number of benefits. These benefits can be considered both from the point of view of the enterprise, the consumer and as a whole. For entrepreneurs, they are associated with the possibility of making responsible decisions, increasing the credibility and trust of customers who are offered environmentally friendly products as well as the implementation of eco-innovations which is associated with cost reduction in the long term. The consumer receives better information about products and services, including their impact on the environment which contributes to raising environmental awareness. Taken as a whole, it strengthens the sector's competitiveness in regional, national and international markets and provides better environmental conditions for society (Sala et al., 2016).

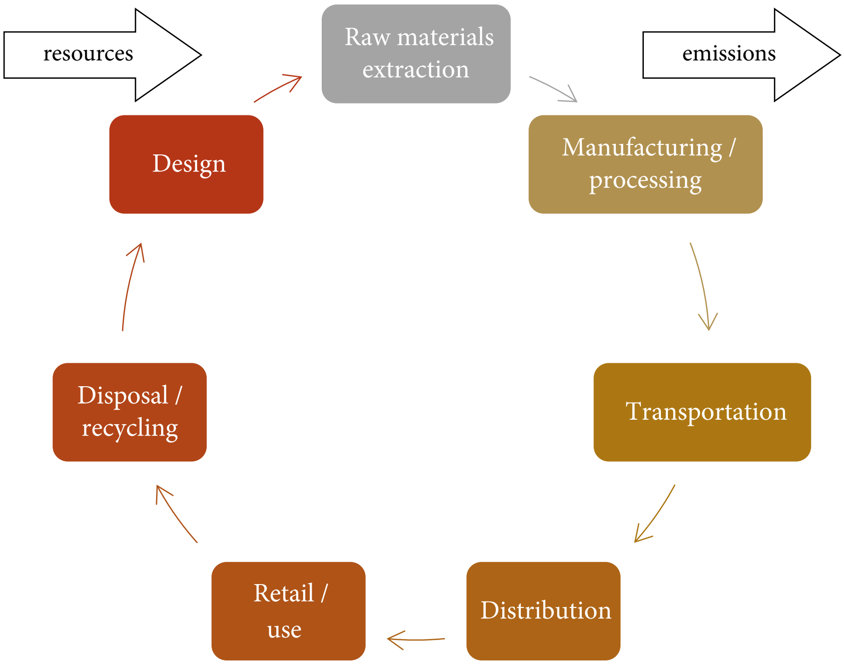

Figure 5.4. Life-cycle assessment

Source: Own study based on (Sala, Reale, Cristobal-Garcia, Marelli, & Pant, 2016).

5.5. Waste management and recycling

Enterprises, institutions and other types of environmentally conscious organizations may use the method referred to as waste management and recycling in their basic activities. The basis for the development of the concept are the problems related to the generation and collection of waste, and the prevention of its production. It is emphasized that with the change of lifestyle, technological progress and growing consumerism, the demand for new, more functional or prestigious products increases. At the same time, their life cycle is shortened. This process applies to most of the goods available on the market, ranging from clothing and food, through household appliances and electronics, and ending with luxury and exclusive goods. Therefore, there is a problem of what to do with products for which the demand has drastically decreased. These products could function successfully in many cases, however, due to market trends and changing fashion, they are withdrawn. The process of losing value as a result of technological progress is known as obsolescence. It applies to all groups of goods, however, it is of particular importance on the RTV market (e.g. mobile phones, video, CD players or cameras) and sports equipment which new collections appearing every year. Waste generated both in households and in industry should be properly managed. The aim of such management is on the one hand to minimize them, on the other hand to reduce costs as well as to obtain additional practical benefits.

Waste management is the collection, transport, processing, recycling or disposal, and monitoring of waste materials. The term usually relates to materials produced by human activity, and is generally undertaken to reduce their effect on health, the environment or aesthetics. Waste management is also carried out to recover resources from it (Bacinschi, Rizescu, Stoina, & Necula, 2010, p. 378).

An important element related to waste management is the implementation of an appropriate conducting concept which can be based on the assumption of "3Rs" reduce, reuse and recycle which classify waste management strategies according to their desirability in terms of waste minimization (Bacinschi et al., 2010, p. 379). According to the authors, waste minimization can take place on four levels:

- the first one is related to the reuse of waste in its original form,
- the second one concerns the segregation of waste, thanks to which it can be properly classified,
- the third one focuses on the analysis of the possibility of using waste by other enterprises,
- the last one is based on development of methods of treating waste in an environmentally friendly way while reducing costs.

Products that have reached the end of their life cycle are problematic waste for the environment. Therefore, it is required to develop an appropriate policy for the management of end-of-life items and other types of production process residues. The best method of reducing waste is prevention which increases the awareness of both businesses and individual consumers. In case of producers, there should be taken into account, first of all, the possibility of using such raw materials, materials, semi-finished products and other parts in the production processes that can be reused in the future. This approach significantly reduces the production of waste, as end-of-life products are recyclable.

Recycling, recovery and reprocessing of waste materials for use in new products. The basic phases in recycling are the collection of waste materials, their processing or manufacture into new products, and the purchase of those products, which may then themselves be recycled (*Britannica*).

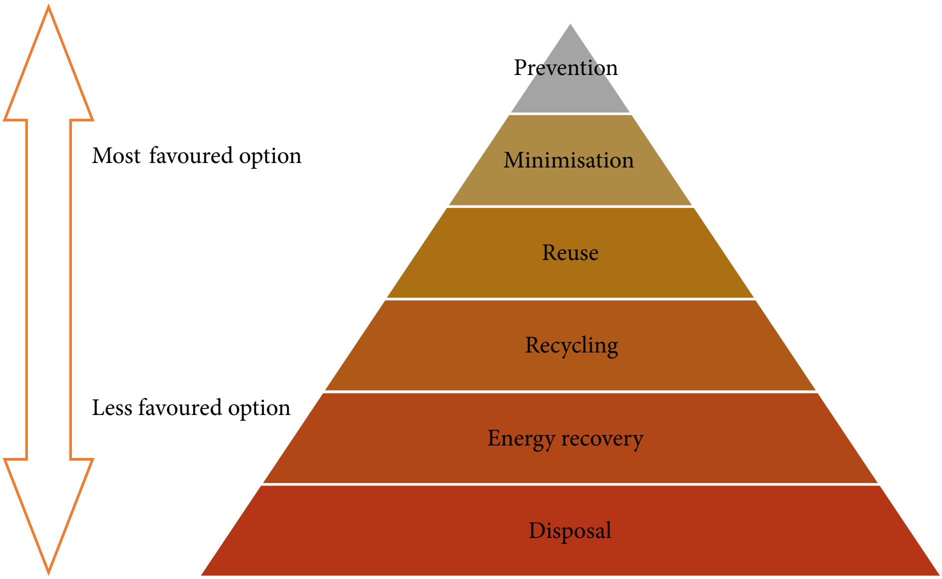

Figure 5.5. Diagram of the waste hierarchy

Source: (Bacinschi et al., 2010, p. 378).

Most of the raw materials and materials used in production processes can be recycled. It covers both steel and cast iron scrap, aluminium as well as paper, wood, plastics and others. The recovered and recycled materials are usually a substitute for raw materials obtained from the natural environment. They can be used by enterprises that used them initially or are used in completely different processes carried out by completely different enterprises. It is indicated that the main advantage of recycling is the reduction of waste in landfills which contributes to the reduction of air, water and land pollution. In addition, companies that emit less pollutants also reduce the costs of their core activities. Savings result from both the use of recovered raw materials and materials as well as the costs of their storage.

5.6. Electronic Data Interchange (EDI)

Electronic Data Interchange (EDI) is a form of information exchange between the computer systems of different organizations. It involves the direct exchange of standardized documents and messages transmitted electronically between the computers of two organizations (Andersen, 1998, p. 2). These business entities conducting business electronically are called trading partners. It should be emphasized that data transmission takes place using electronic equipment for data processing (including digital compression) using cable, radio, optical technologies or any other electromagnetic means. Most importantly, the data is exchanged automatically without human intervention

EDI is a method of communicating between organizations participating in an economic, administrative or other undertaking, consisting in automatic electronic transmission of formatted documents (Kot, Starosta-Patyk, & Krzywda, 2009, pp. 60–61).

The main assumption behind the introduction of EDI standards and their application is the increasing number of paper documents, high costs of their transmission and the fact that errors appearing in commercial documents translate into delays in business transactions and an increase in the operating costs of enterprises. At the same time, the progressive computerization and its dissemination mean that documents in paper version (e.g. for environmental reasons) go down and are replaced by electronic versions.

The popularization of EDI is also caused by the constantly growing requirements of today's market, e.g., by the necessity to introduce quick deliveries of products precisely tailored to customer requirements. As a result, only those entrepreneurs and their business partners who are able to communicate well and efficiently with each other are able to survive and meet the requirements of contractors. Therefore, the use of EDI, where this communication takes place automatically, allows to quickly respond to market demand and reduces inventory and shortens the time of order fulfilment (Kosmacz-Chodorowska, 2013, p. 18).

Initially, EDI techniques were developed in the transport, pharmaceutical, automotive and financial sectors. However, the development of many standards caused chaos and disorganization, therefore work was undertaken on a common document standard for the needs of tele transmission between computer systems. Currently, two standards are most popular in the world—the American ANSI ASC X12 and the international UN/EDIFACT, used in Europe.

Today, EDI is a well-developed system, deeply rooted in global business. It is estimated that in the United States alone, Electronic Data Interchange is used by over 100,000 companies, including giants such as Federal Express, Eastman Kodak, American Airlines, Nike, Staples, National Bank, JC Penney, and Prudential Insurance. In addition, many US government organizations also accept and transmit documents electronically (Edison SA, 2020).

In Europe, EDI is used by all large retail chains as well as many production plants and distributors. Some retail chains exchange up to tens of thousands of documents with their suppliers a month. The largest EDI users include Auchan, Carrefour, Lidl, and Castorama.

EDI standards are a set of strictly defined semantic rules as well as data catalogues and codes used to build, among others, EDI messages, which should be equated with paper documents. Each standard EDI document is therefore an equivalent of a paper document, e.g., order, delivery note, invoice. Figure 5.6 shows a schematic of standard EDI.

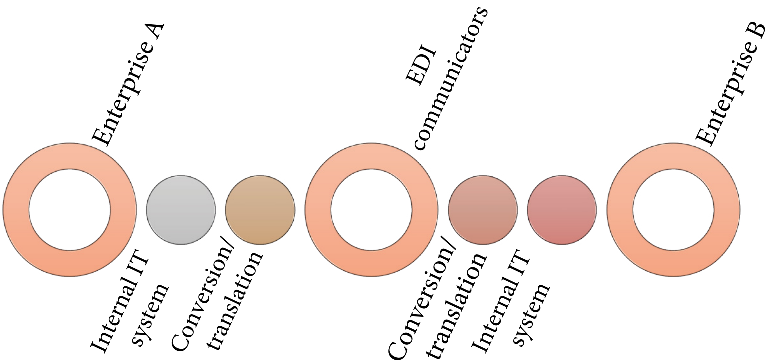

Figure 5.6. Schema of Electronic Data Interchange (EDI)

Source: Own study based on (Kosmacz-Chodorowska, 2013, p. 19).

EDI messages are created in a computer-readable format that enables their automatic and unambiguous processing on a specific set of words, generally known as data elements. Among standard messages, four basic groups can be distinguished:

1. Transaction messages: most often used due to the possibility of exchanging data necessary for the purchase and sale of products between the buyer and the seller. This group includes messages such as an order, invoice or price catalogues.
2. Information messages: used to provide constant data about goods and business partners.
3. Transport messages: include elements such as a transport order or a shipping/delivery note, thanks to which company can better organize the delivery process.
4. Financial messages: used to make payments and inform about cash movements. This group includes messages such as transfers or information about account traffic.

Such a wide range of standard documents that can be exchanged using EDI enables the exchange of documents with any business partner, if its technological advancement allows it. Figure 5.7 shows an example of a 9-steps EDI message flow between the buyer and seller.

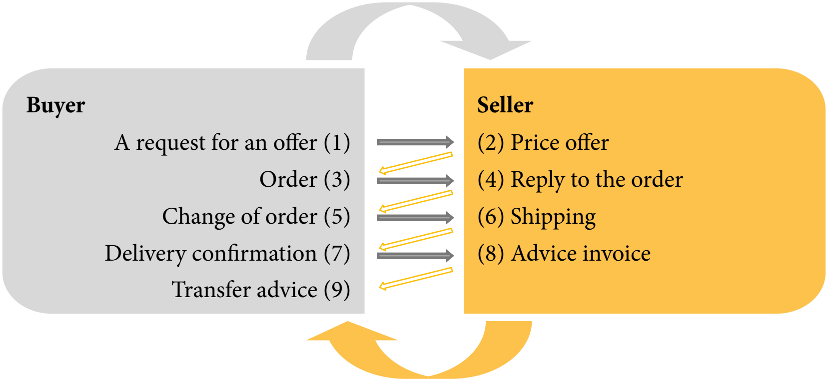

Figure 5.7. An example of the flow of EDI messages in commercial transactions

Source: Own study based on (Kosmacz-Chodorowska, 2013, p. 19).

The management of each company before deciding to apply EDI should be aware of both the pros and cons resulting from this implementation (Table 5.1). Assessing investments incurred on EDI, it should be compared to the changes and benefits it will have for the entire company, including the costs incurred for the reorganization of those departments that will be directly involved in EDI. For example, electronic invoicing and electronic money transfers can bring company the greatest benefits in the accounting department, and will also be noticeable in sales, production and more.

Table 5.1. Advantages and disadvantages of Electronic Data Interchange

Advantages	Disadvantages
• shortening the terms of order processing and delivery times • eliminating labour-intensive administrative and office activities • limiting additional communications due to any arrangements • standardization of the form, content and circulation of information provided • minimizing the costs of using documents • modernization of the organization and technology of enterprise management • reducing errors and increase accuracy by eliminating duplication of data from one paper document to another or manually entering data into the business application • inventory optimization by receiving appropriately early accurate information on customer needs and delivery times • improving the circulation of payments as a result of shortening order processing time and invoice verification time	• the need to create a detailed action plan for the implementation of EDI • the need to remodel business processes and procedures • the need to incur high costs of purchasing EDI software and its integration with the company's current IT system • conducting numerous training courses for employees and business partners • a cost-intensive and labour-intensive period of testing the system using EDI for sending commercial documents • high costs of leased lines and the use of the ICT network

Source: Own study based on (Fajczak-Kowalska, 2012, p. 32; Kosmacz-Chodorowska, 2013, pp. 20–21).

5.7. Virtual enterprise

In the last few years, virtual organizations have become a symbol of modern economic and social development. The concept of a virtual enterprise was introduced by Davidow and Malone (1992) and popularized by Byrne (1993).

A virtual organization is a temporary network of independent companies, suppliers, customers and even competitors connected with each other in an information and technological manner (Byrne, 1993). The purpose of these relationships is: exchange of know-how, cost diversification, mutual access to markets.

The most common view is that virtual organization is understood as something electronic, digital, cyber-spatial, elusive (Kisperska-Moroń, 2008, p. 9).

However, the term virtual organizations has been commonly divided into two main groups, namely virtual organizations in terms of processes and virtual organizations in terms of structure (Saabeel, Verduijn, Hagdorn, & Kumar, 2002, pp. 4–5). The process approach, i.e., coordination orientation, focuses on: behaviours and actions, identifies the organization on the functional side. The process approach also considers how the organization reacts to changes in the environment and assumes the continuous design and implementation of new business processes (Brzozowski, 2010, p. 39).

> A virtual organization is the right kind of collaborative organization to explore the competitive environment (Sieber, 1999, p. 213).

In the structural approach, a virtual organization is a specific organizational structure, based on various forms of cooperation in order to jointly use competences, knowledge and other resources to create a specific good or to use an emerging market opportunity (Burn, Marshall, & Barnett, 2001).

The virtual business model is characterized primarily by flexibility. A group of cooperating enterprises that are able to unite in order to take advantage of emerging market opportunities, who usually terminate the cooperation after the completion of these goals and the use of cooperative abilities. Each enterprise engaging in the creation of a virtual organization participates in creating added value only within its own key competences. Technology plays a key role in creating this hybrid. Human teams, composed of different members of a virtual organization, cooperate with each other simultaneously, not sequentially via the Internet in real time (Jacobsen, 2004, p. 15).

It is worth noting, however, that virtual enterprises have many common and diverse features with traditional organizations (Table 5.2).

Table 5.2. Similarities and differences between real and virtual enterprises

Similarities	Differences
• are created and operated by people • are focused on achieving the highest possible profits • are characterized by a division of work, roles and functions in the organization • consist of material and non-material factors • are capable of achieving the intended goals	• traditional organizations often exist for an extended period of time, a virtual enterprise is very short and covers the implementation period of a specific project • the traditional organization contains more material elements and relies more on material capital • a virtual enterprise cannot function without modern IT technology, unlike a traditional organization • virtual enterprise has an advantage in terms of speed and flexibility in adapting to changes • virtual enterprise is characterized by a faster appearance and disappearance on the market and the ability to seize market opportunities

Source: Own study based on (Brzozowski, 2010, p. 49; Kalisz & Szyran-Resiak, 2018, p. 481; Kisielnicki, 2001, p. 277).

The evolution of an enterprise into a virtual enterprise is determined by the following variables (Brzozowski, 2010, p. 110):

- direction: describes the vision and understanding for the future course of action in conjunction with its stakeholders,
- form: the method of transforming a goal into specific activities, indicates the degree of flexibility and responsibility in creating systems and structures for specific operations,
- communication: it covers organizational culture and processes related to collecting, grouping, processing and sending information,
- adaptation: it defines the learning processes that determine the ability to adapt to changes in internal and external conditions.

The process of creating a virtual organization best reflects the life cycle of a virtual organization. Its diagram is presented in Figure 5.8. Participation in a virtual enterprise is particularly attractive for smaller companies, as it helps them eliminate the differences between the advantages of large entities in terms of achieving economies of scale. A small company as a participant is able to access all kinds of resources that it would not be able to develop under normal conditions.

Virtual enterprise creates conditions for offering both simple solutions, such as a small product, to more comprehensive ones, such as technical consulting, service and support. The improvement of conditions also applies to the scale of operations from the local, regional and global market. The strengths and weaknesses of the virtual enterprise are presented in Table 5.3.

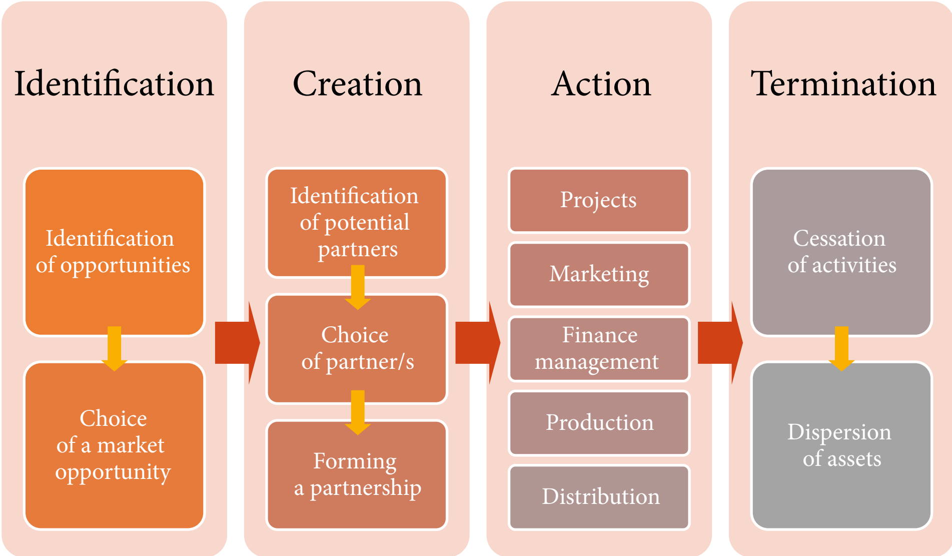

Figure 5.8. Virtual organization life cycle model

Source: Own study based on: (Strader, Lin, & Shaw, 1998).

Table 5.3. Advantages and disadvantages of virtual enterprise

Advantages	Disadvantages
• high flexibility and adaptability • faster transaction execution • increase in productivity • conducting a common policy regarding the operation of the organization • reduction of investment outlays necessary for the development of the organization • high quality of services resulting from focusing on the core business and cooperation with competent and effective suppliers • reduction of legal service of transactions to the necessary minimum	• the necessary trust in all organizations cooperating within virtual organizations • lack of patterns of behaviour • difficulties in developing the principles of distribution of the company's profit • virtual • difficulties in identifying the company and its partners in the network • the possibility of participation of incompetent and untested enterprises

Source: Own study based on (Kalisz & Szyran-Resiak, 2018, p. 493).

5.8. World Class Manufacturing (WCM)

As it was already noted in previous chapters, the automotive sector is the cradle of many traditional and modern concepts and management methods. Their formation is favoured primarily by the size of contemporary enterprises in this industry—among which all major players are global organizations—with very strong competition and the specificity of the product. Hence, a great motivation to look for opportunities to stand out, attract attention, be among the best in the world and actually become such. One way to achieve this goal is to use World Class Manufacturing (WCM) (Walczak, 2015, p. 114).

The name World Class Manufacturing was introduced into literature by Hayes and Wheelwright in 1984. These authors made a comparison between the organization of processes in Japanese, German and American enterprises. They considered six factors particularly important for the existence of WCM: employee skills, technical competence management, quality competition, employee participation, renewal in the field of production engineering and continuous improvement

World-class production is a project based on the Toyota Production System (TPS) and the lean manufacturing concept, assuming in the final version a production characterized by zero accidents, zero losses, zero defects and zero failure. WCM is also a way of organizing an enterprise that allows to achieve the highest possible level of production organization by implementing modern concepts, methods and management tools (Dudek, 2013, p. 71).

World Class Manufacturing is an integrated management system that allows achieving the highest level of international production excellence. It combines the best methods, concepts and management tools that aim to achieve the best global competitive position through the continuous improvement of the company's operations, production processes in the flow of raw materials, materials, components and finished products from the supplier to the final customer (Piasecka-Głuszak, 2017, p. 53).

The WCM name is most often applied by large enterprises with international capital, the intention of which is to increase the efficiency of their operation, among others as a result of cost rationalization (Gajdzik, 2013, p. 31).

WCM is based on two pillars: technical and management. The technical pillar consists of a set of tools used in modern production companies. The management pillar is a course of action carried out during the implementation of individual elements included in the technical pillar (Walczak, 2015, p. 115).

Each of the pillars is a set of guidelines that are divided into the so-called steps (each pillar has its precisely defined seven steps). Then, the progress of implementation of each pillar is assessed during control audits (internal and external). On this basis, each of the pillars receives points which, when summed, give a complete picture of the advancement of WCM implementation in the enterprise (Dudek, 2013, p. 72). Production plants wishing to become a world-class manufacturer must undergo a certification process. Depending on the result obtained, certificates are issued.

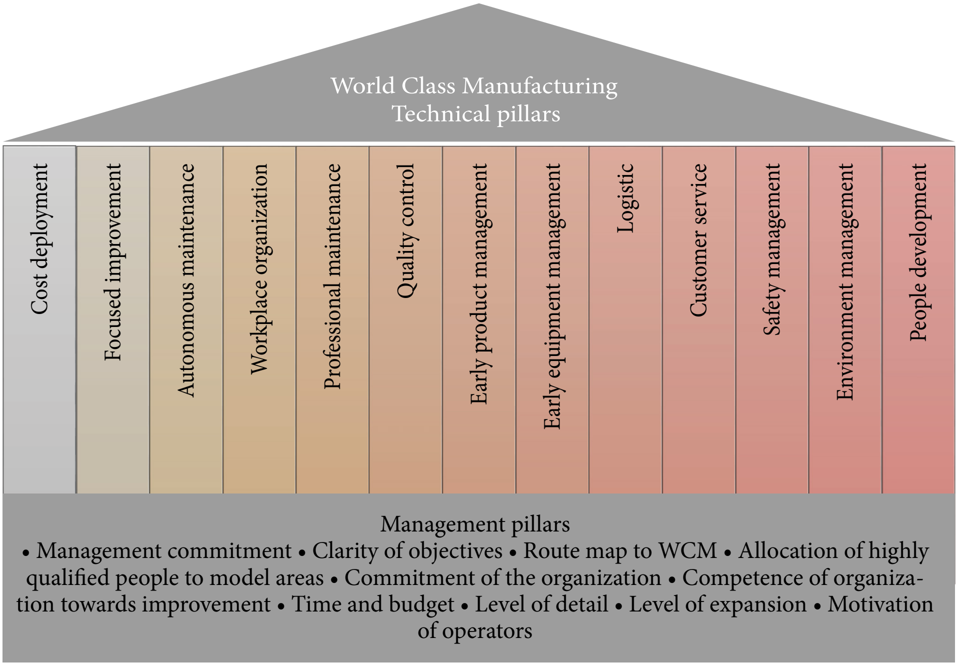

Figure 5.9. Main technical and management pillars of WCM (Temple of WCM)

Source: Own study based on (Dudek, 2013, pp. 71–72; Kruczek & Żebrucki, 2012, p. 788; Piasecka-Głuszak, 2017, p. 57).

The practiced way to assess the degree of WCM implementation is to determine the Index Implementation Methodology (IIM) index. In order to get a better visualization of the advancement of World Class Manufacturing implementation in the enterprise, medals are contractually applied, depending on the obtained indicator value, e.g. (Piasecka-Głuszak, 2017, p. 58):

- over 50 points—bronze medal,
- over 60 points—silver medal,
- over 70 points—gold medal,
- above 85 points—the enterprise reaches the level of WCM.

These scoring limits depend on business preferences and may be slightly higher. Each pillar is assessed on a scale of 0–10 and obtaining 0 points in a particular area means that the problem is not defined or understood.

Deploying WCM in an enterprise requires consideration of internal and external factors to a successful deployment. The behaviour and attitude of employees in the company, and employees at all levels, are considered the most important. The strengths and weaknesses of the World Class Manufacturing are presented in Table 5.4.

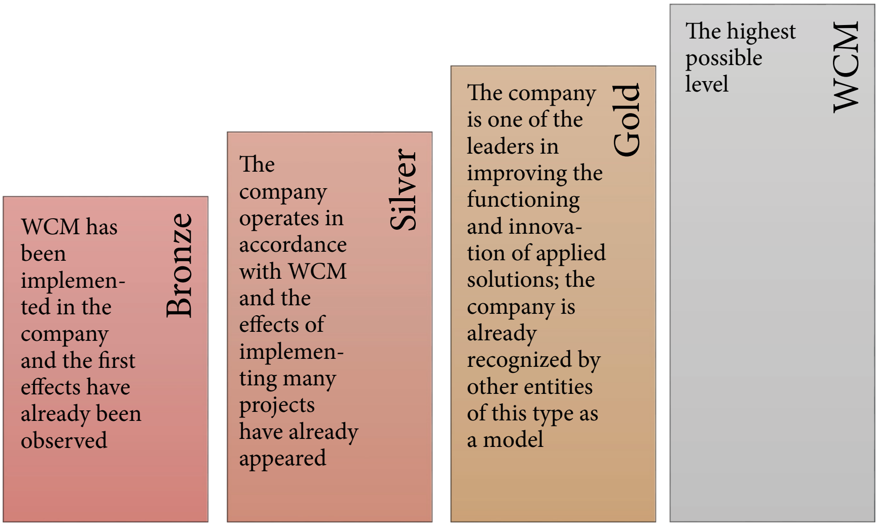

Figure 5.10. WCM certificate levels

Source: Own study based on (Gajdzik, 2013, p. 34).

Table 5.4. Advantages and disadvantages of World Class Manufacturing

Advantages	Disadvantages
• allows to reduce losses • optimize logistics flows • greater efficiency • greater flexibility • no space constraint • ensuring the timely execution of customer orders • improving working conditions for employees	• need for cost justification • resistance to change • lack of management support • lack of knowledge • lack of appropriate monitoring • lack of employee education and training • inadequate tools and equipment

Source: Own study based on (Felice, Petrillo, & Monfreda, 2013; Porter, 2001).

5.9. Quality Function Deployment (QFD) and House of Quality (HOQ)

The Quality Function Deployment (QFD) method is used to design new products and services and to modify the existing ones so that enterprises meet (as much as possible) the requirements specified by the customer. It belongs to the customer-oriented design methods. This means that when designing, the work does not start with planning the features of the product, but with the customer's requirements, and then designing the product or service to satisfy those requirements (Wolniak & Sędek, 2008, p. 179).

The discussed method was developed in the 1970s in Japan. The authors of the method are considered to be Akao and Mizuno. It was used for the first time at the Kobe shipyard and then the Japanese car industry.

Quality Function Deployment is a method of planning and developing a project or service, enabling research teams to make a precise specification of customer needs and requirements, and then translate them into the parameters of the product or service, its components and the parameters of the production process itself.

Currently, it belongs to the customer-oriented design methods. It is particularly important nowadays in the conditions of implementing Industry 4.0, where products must be designed and manufactured according to the customer's needs in conditions of strong saturation with automation and computerization. Moreover, the QFD method is often classified as a marketing research method.

In the QFD method, the original "customer voice" should be horizontally introduced into the following phases of product development:

- product planning,
- planning production processes, and
- planning production operations.

Then it should come back to the client as a new system. In addition, the "customer voice" must also be introduced vertically—by system levels. Often, this is where a mistake is made, and the customer's needs are lost sight of. For this reason, it is very important to conduct a systematic and planned procedure that does not allow any essential elements to be omitted in the design process (Wolniak, 2017, p. 2).

During the development and application of the QFD method, a diagram is used which, due to its specific shape, is commonly called the House of Quality (Figure 5.11). The standard House of Quality diagram consists of the following nine sectors, but their number can be modified depending on the needs of the organization and the complexity of the analysed problem (Zimon & Gawron-Zimon, 2014, pp. 1080–1083).

The first sector includes requirements that are important for the client and are treated as a starting point for further considerations. The respondents should be able to report information such as: cost-effectiveness of deliveries, speed of deliveries, regularity of deliveries, completeness of deliveries, the possibility of placing orders around the clock, the choice of hours and forms of product delivery, the length of the guarantee, the method of solving existing problems, etc.

Second sector contains information on the importance of individual customer requirements. Segregation is very important here as it allows company representatives to identify areas of improvement company need to focus on in particular.

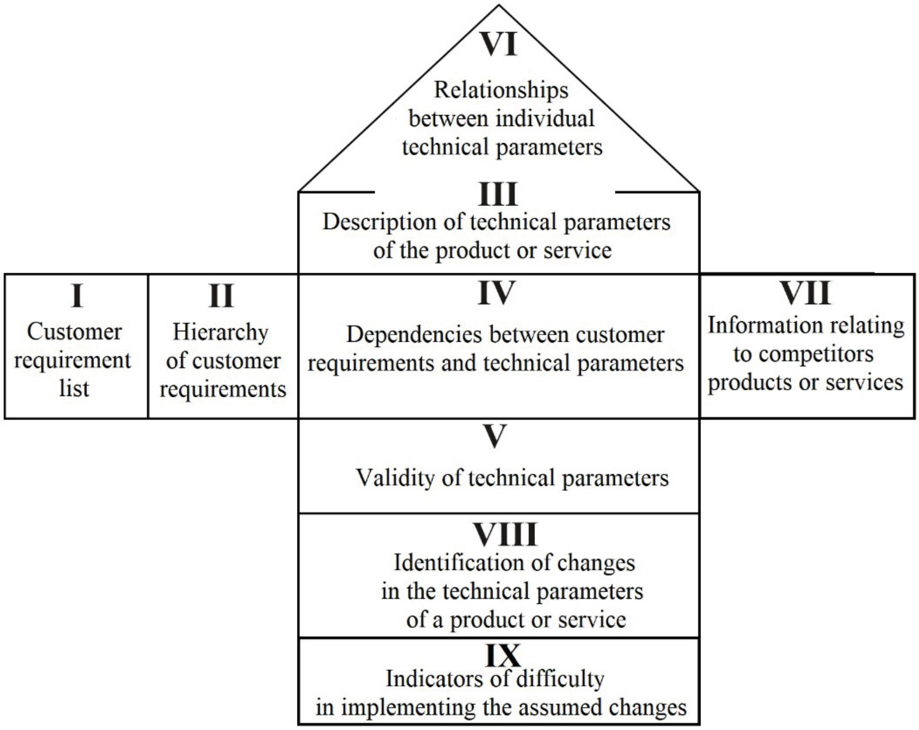

Figure 5.11. House of Quality diagram

Source: Own study based on (Zimon & Gawron-Zimon, 2014, pp. 1080–1081).

In third sector, the client's requirements in Sector I are "translated" into a specialist language. Technical parameters should be formulated in such a way that it is possible to express them in units that may be subject to possible corrections.

Fourth sector is dedicated to recognizing the dependencies between customer requirements (sector I) and technical parameters of the service (sector III). The occurring correlations can be strong, medium or weak. The values of each degree of correlation intensity are selected individually according to the needs of people using the QFD method. Based on the established dependencies, designers receive information specifying which technical parameters of the service should be corrected so that it more fully meets the needs of customers.

The importance of technical parameters is specified in fifth sector. When carrying out such an analysis, it is necessary to distinguish parameters whose modification will have the greatest impact on the increase of customer satisfaction.

In sixth sector, the correlation between the individual technical parameters of the service offered is established.

In seventh sector, the proposed service is compared with the services provided by competing companies. The management of an organization should strive to compare the services provided through its distribution channel with those of competing channels. The information obtained in this way should be an inspiration to implement improvement actions.

The analyses carried out so far are summarized in sector eighth. After carrying out the activities and operations that resulted in the filling of the previous sectors of the House of Quality, it can be concluded that the working group has an appropriate idea of the service and its individual parameters. Based on the analysis of the collected data, it is possible to define the target values that the service must have in order to meet the customer's requirements and be competitive with the services provided by other companies.

In the last sector, an assessment is made of the difficulties in implementing the changes proposed in the eighth sector. The assessment should be realistic and take into account the financial, technological and resources available to the enterprise. The management of the organization should be aware that not all changes proposed by the client can be implemented, and the organization needs to mature or prepare properly for some of them.

The application of the QFD method in enterprises will allow not only to precisely define customer requirements, but also to change and improve individual technical parameters of the physical product flow processes.

5.10. Theory of constraints (TOC)

The essence of the theory of constraints is a methodology for identifying the most important limiting factor (i.e. constraint) that stands in the way of achieving a goal and then systematically improving that constraint until it is no longer the limiting factor. In manufacturing, the constraint is often referred to as a bottleneck. Assuming that every system functioning in the economy has certain limitations, the following methodological stages (see Figure 5.12) can be distinguished (Goldratt, 1990, pp. 4–8):

1. Identification of system limitations. When this is achieved, remember to prioritize the individual constraints according to their impact on the achievement of goals in the enterprise. Otherwise, many resources may be devoted to tackling insignificant limitations, while the actual constraints, with a significant impact on the overall system, will remain.
2. Decide how to exploit the system's constraints. After deciding how to manage the limitations, you should focus on how to manage the rest of the system resources, which are not the limitations. Considering the fact that every wasted

minute due to the system not working is a waste that cannot be recovered, you must take the necessary measures to ensure the uninterrupted operation of the system to achieve maximum production capacity.
3. Note, however, that there is still room for many more improvements. Restrictions are not supernatural actions; you can do a lot with them. Regardless of the limitations, there must be a way to reduce their restrictive effect.
4. Through continuous improvement in the area of the identified limitation, it can be eliminated. However, this will not immediately maximize the efficiency of the production system as it will be affected by the next constraint.
5. If in the previous steps a constraint has been broken, go back to step 1. However, care should be taken that inertia does not cause the system to become constrained. It often happens that in the organization, due to the existence of limitations, there are many rules, both formal and informal. Once a constraint is removed, usually no revision of the rules is performed. As a result, today's systems are limited mainly by management policy constraints. We meet restrictions of the marketing policy more often than actual market restrictions. The bottleneck in the production hall is less often, and more often the restrictions result from the manufacturing policy. Restrictions rarely apply to suppliers, and often to purchasing policy. It should be emphasized that most policies were correct at the time of their creation, but after the removal of restrictions, they should be modified accordingly.

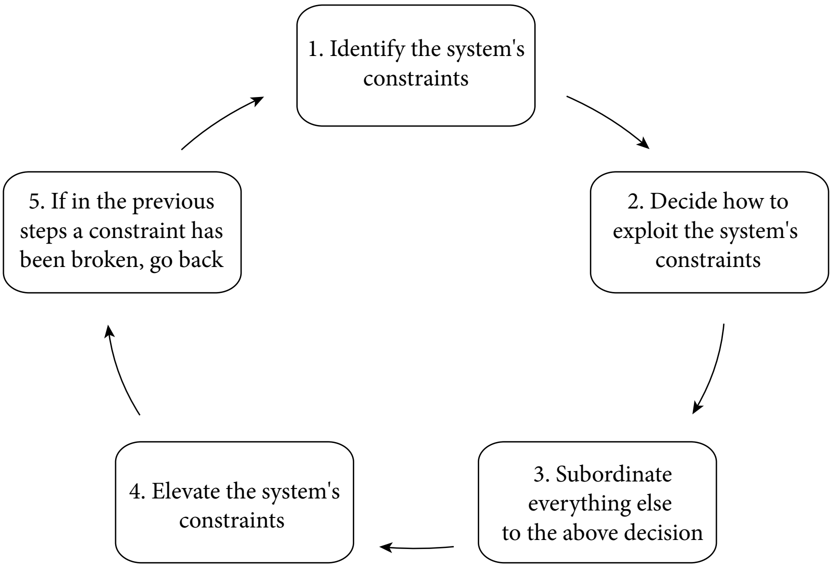

Figure 5.12. Theory of constraints methodology

Source: Own study based on (Goldratt, 1990, pp. 4-8).

It should be emphasized that the application of the theory of constraints principles in practice requires a comprehensive view of the entire production system. The main principle of theory of constraints is concentration, i.e. focusing on the most important issues. This means that all processes and positions should be supervised, although not all equally. The most attention should be paid to tasks that are crucial to the system as a whole. Appropriate identification of constraints offers many opportunities for business improvement and it positively affects the performance indicators (Trojanowska & Dostatni, 2017, p. 88).

5.11. Drum Buffer Rope (DBR)

Drum Buffer Rope (DBR) is the theory of constraints scheduling process focused on increasing flow by identifying and leveraging the system constraint. DBR was developed by Goldratt, the creator of theory of constraints (Goldratt & Cox, 2016). TOC requires the use in practice of a three-element production programming system, called Drum Buffer Rope, taking into account the production of products according to the transport batch and processing batch (an example of a DBR system with a single bottleneck is shown in Figure 5.13). The characteristics of these elements are as follows (Cox III & Schleier, 2010):

- Drum: gives the process an appropriate production rhythm, according to the adopted operational plan, taking into account "bottlenecks".
- Buffer: material stocks placed in the process before bottlenecks; There are three types of bottleneck inventories: performance-related, associated with the required number of items delivered, non-performance-related bottlenecks—located after operations at a position identified as a bottleneck.
- Rope: this is the principle of delivering materials or elements at the workplace according to the "bottleneck".

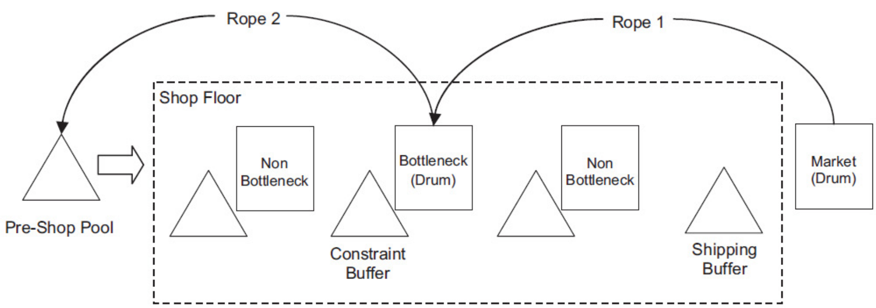

Figure 5.13. Drum Buffer Rope

Source: (Thürer, Stevenson, Silva, & Qu, 2017, p. 117).

The implementation of DBR allows to optimize the use of production resources, which results in better economic results of the company. However, it is important to measure the performance of operating results over time, including those based on indicators. It should be emphasized that the purpose of the indicators is to motivate the people involved to do what is good for the organization as a whole. Comparing the performance over time (before / after DBR) can provide company management with answers about the implications of implementing DBR in the organization. Understanding these effects can help you make decisions about how to best allocate resources and prioritize actions (Telles, Lacerda, Morandi, & Piran, 2020, p. 2).

It should be emphasized that although the DBR theory has its origins in the 1980s and 1990s, contemporary research confirms the effectiveness of the proposed solutions. The results obtained by Telles and others (2020, p. 7) show that after the implementation of DBR in the analysed company, the complex efficiency of the computer production line increased by an average of 19%, the display production line increased by 16%, and the electronics production line by 4%.

The usefulness of DBR methodology in the remanufacturing environment should also be noted. Remanufacturing is an industrial process that restores used products to a new condition, including repair, overhaul and regeneration processes. More and more products are being regenerated. The partial list of products includes airplanes (both military and commercial). aircraft parts, auto parts, diesel, gasoline and turbine engines, locomotives and railroad cars, and electronic goods.

Given that scheduling for remanufacturing is more complex and the planner has to deal with more uncertainty than in a traditional production environment. In order to properly create a production schedule in this environment, it must be able to cope with several complex factors that increase variability. The schedule must be adapted to conditional routes, routes that may or may not be selected due to the condition of the vessel. The schedule must also be adapted to dependent events, e.g. operation B cannot start until operation A is completed. Drum Buffer Rope (DBR) offers an extremely robust planning method. The schedule created with DBR can include both conditional routes and dependent events (Guide, 1996, p. 1081)a routeing that may or may not be taken due to the condition of the unit. The schedule must also be able to cope with dependent events, e.g. operation B cannot begin until operation A is completed. Drum Buffer Rope offers an extremely robust planning method. The schedule created with DBR can include both conditional routes and dependent events (Guide, 1996, p. 1081).

5.12. Group technology (GT) and cellular manufacturing (CM)

Group technology (GT) is a production philosophy that is based on the use of similar, repetitive activities. It is a widely applicable concept, potentially affecting all areas of a manufacturing organization. One particular application of GT is cellular manufacturing (CM). CM consists in processing sets of similar parts (families of parts) on dedicated clusters of different machines or production processes (cells).

CM is a concept commonly used to achieve Just-In-Time (JIT) production. It should be emphasized that new technologies often support or even dictate the use of the CM approach. Support is often in the form of emerging information technologies such as computer coding systems for parts in the cell production. On the other hand, the need to use CM results from the use of robotics and other forms of mechanized and automated material handling systems, as well as the desire to build closely related production systems with low throughput times. Effective use of these philosophies and technologies essentially requires a production approach based on a cellular structure (Wemmerlöv & Hyer, 1987, p. 413). This concept is now used in many production environments. The implementation of GT and CM brings many benefits, the most important of which include (Heragu, 1994, p. 203):

- setup time reduction,
- work-in-process inventory reduction,
- material handling cost reduction,
- equipment cost and indirect labour cost reduction,
- improvement in quality,
- improvement in material flow,
- improvement in machine utilization,
- improvement in space utilization,
- improvement in employee morale.

The main difference between the traditional manufacturing environment and the cellular manufacturing environment is the grouping and arrangement of machines. In traditional environments, machines are usually grouped based on their functional similarities. In contrast, in a cellular production environment, machines are grouped into cells, each of which is dedicated to the production of a specific family of parts. Typically, the machines in each cell differ in function. Such a system, in which sets of machines are dedicated to specific families of parts, allows for easier production control.

The main goal of a CM system design is to create machine cells, identify part families, and connect part families to machine cells to minimize intercell movement. When designing a CM system, a number of constraints must be taken into account, such as available machine capacity in each cell, safety requirements, location, number and size of cells, etc. (Heragu, 1994, pp. 203–204).

The CM approach is most commonly used when the production system consists of mid-volume and mid-variety product mixes to reduce lead time, setup costs, material handling, and work in progress. Many methods have been developed to address the above issues, ranging from the similarity coefficient and clustering techniques to mathematical modelling (eg, constrained programming or dynamic programming).

In addition, to increase the efficiency of GT and CM-based production systems, they are often analysed from a broader point of view, covering areas such as scheduling, production and workforce planning, supply chain management, queueing theory, layout and facility localization issues (Alimian, Ghezavati, & Tavakkoli-Mogaddam, 2020, p. 1284).

5.13. Demand Chain Management (DCM)

Nowadays, companies connect their customers and suppliers into tightly integrated networks using the so-called Demand Chain Management (DCM). DCM is defined as a practice that manages the supply chain and coordinates the supply chain from end customers back to suppliers (Vollmann, Cordon, & Heikkilä, 2000, pp. 81–90). End customers trigger actions up the supply chain, and products and services are pulled (not pushed) from one link to another based on demand.

The importance of the DCM concept has dynamically evolved over the past years with the development of the Internet. Due to the fact that DCM requires deep integration between all business partners to be successful, such connections have only become possible thanks to information technology. It is worth noting that in the pre-internet era, there were no perfect solutions to trade-offs between low cost, rich content, real-time data, and wide deployment in supply chains using traditional methods such as EDI and Kanban.

The Internet has successfully solved these problems and allowed for tight integration between each partner in the supply chain. Once impossible, real-time demand information and inventory visibility is becoming essential for supply chain forecasting, planning, scheduling and execution. Real-time information is sent immediately backwards through these network-based, demand-driven supply chains while inventory flows rapidly forward (the comparison of supply chain integration strategies is presented in Figure 5.14).

Most importantly, goods and services are delivered quickly and reliably when and where they are needed. The more integrated the flow of data between customers and suppliers, the easier it is to balance supply and demand across the network. Greater online coordination with reduced lead time helps overcome the bull effect and contributes to higher productivity (Frohlich & Westbrook, 2002, pp. 730–732).

This approach to demand chain management creates a synergy effect between traditional supply chain management and marketing by starting from the specific needs of customers and designing the chain to meet those needs, rather than starting with the supplier / manufacturer and working for the forwards. Such integration seems mandatory in today's market where customers benefit from accessing their accounts in real time, making changes to customized product configurations, and communicating their individual service requirements (Jüttner, Christopher, & Baker, 2007, pp. 377–379).

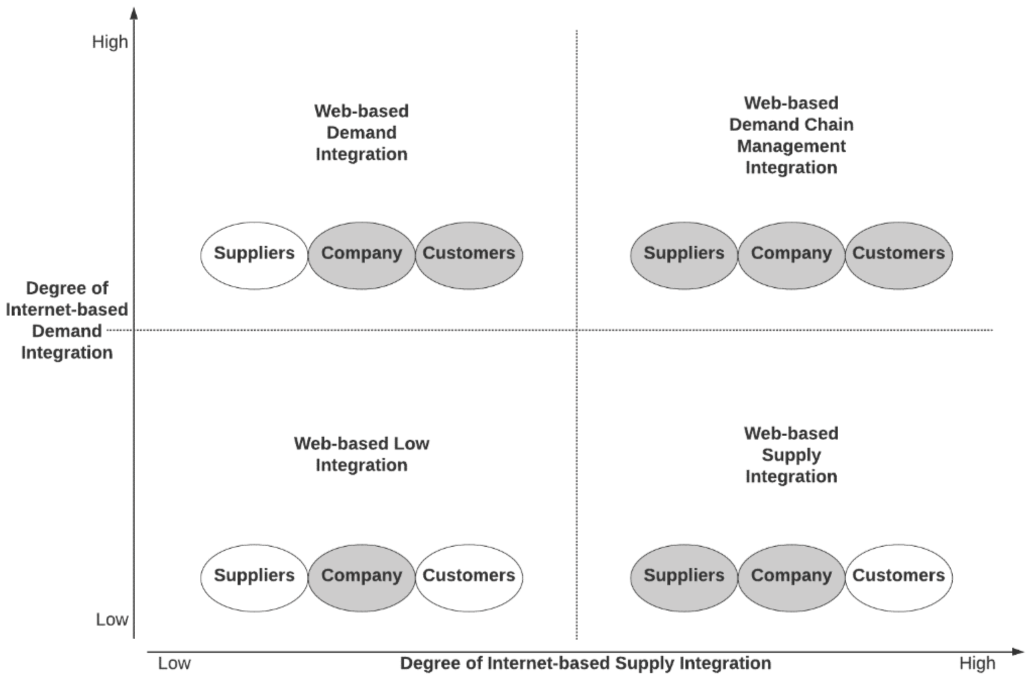

Figure 5.14. Four web-based supply chain integration strategies

Source: Own study based on (Frohlich and Westbrook, 2002, pp. 730–732).

It should be emphasized that Demand Chain Management is a much broader concept than the traditional Supply Chain Management. The broad scope of DCM concepts stems from the synthesis of demand fulfilment and demand creation aspects in the supply chain management and marketing. In other words, Demand Chain Management focuses on detecting customer response in real time and then reacting quickly to it.

Some researchers saw this as a mechanism for understanding customer requirements and turning this understanding into active strategies and plans for the entire group of companies involved in the network. In this context, Demand Chain Management is seen as an integrative function of the supply chain and marketing that can be explained by three sub-functional processes (shown in Figure 5.15): managing integration between supply and demand processes; managing the structure between integrated processes and customer segments; managing the relationship between marketing and supply chain management (Deshmukh & Mohan, 2017, p. 324).

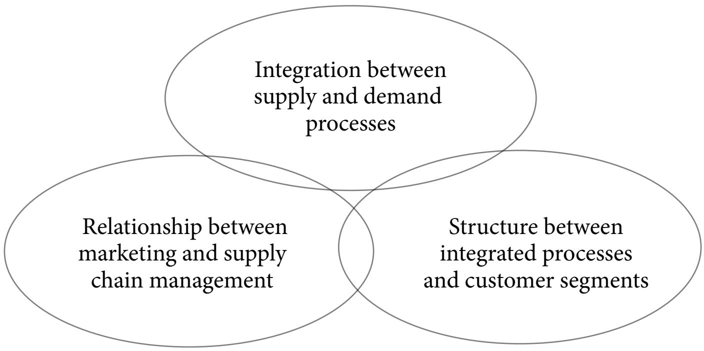

Figure 5.15. Demand Chain Management processes

Source: Own study based on (Deshmukh and Mohan, 2017, p. 32).

5.14. Competitive intelligence (CI)

The origins of the concept of competitive intelligence can be traced even over 5,000 years ago in Chinese religious and historical translations relating to the concept of intelligence. As early as 2,400 years ago, Sun Tzu wrote *The Art of War*, in which he detailed how to develop intelligence for military purposes. The idea of CI is also well reflected in the words of Frederick the Great (1740–1786) that "It is pardonable to be defeated, but never to be surprised" (Calof & Wright, 2008, p. 718).

However, it should be emphasized that over the years the concept of CI has changed and evolved. Currently, what we call as CI is defined as an ethical and systematic process, program and function of gathering, analysing, and managing information about the external environment. This information can be used to make decisions at any level, leading to a competitive advantage. Competitive intelligence manages information about the external environment and is proactive. Thanks to this, it can be used to assess the current and potential external environment, as well as threats and opportunities (Shujahat et al., 2017).

The importance of CI in the process of making managerial decisions is also indicated. SCIP (Strategic & Competitive Intelligence Professionals) defines CI as the process of legally and ethically gathering and analysing information about competitors and the industries that they operate in order to help your organization make better decisions and reach its goals. The Competitive Intelligence Ning (a discussion forum for competitive intelligence practitioners), defines CI as the interpretation of signals from the environment for an organization's decision makers to understand and anticipate industry change (Calof, Arcos, & Sewdass, 2018, p. 718).

It can be seen that the concept of CI is related to the concept of environmental scanning, which suggests a broader view of the organization's external environment. Thanks to these processes (shown in Figure 5.16), the organization senses, perceives, interprets and acquires knowledge, thus getting to know its competitive environment. The organization learns from the environment in three steps (de Almeida, Lesca, & Canton, 2016, p. 1284):

1. Scanning (monitoring and data collection).
2. Interpretation (giving sense to the data collected).
3. Learning in a cyclic process.

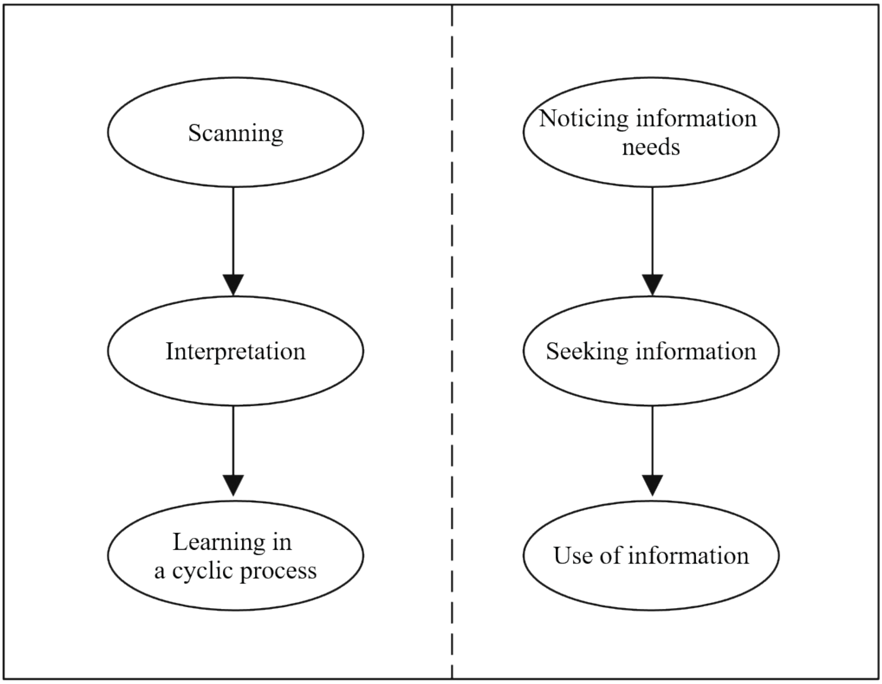

Figure 5.16. CI processes

Source: Own study based on (de Almeida et al., 2016, p. 1284).

In addition, it is worth noting that the collection and sharing of information and knowledge depends on the so-called information behaviour, which includes three groups of activities (de Almeida et al., 2016, p. 1284):

1. Noticing information needs.
2. Seeking information.
3. Use of information.

After noticing information needs, the search for information begins, and individuals look for information and change their state of knowledge. In an information exploitation activity, individuals select and process relevant information. Information-seeking can be conceptualized as the process of constructing knowledge and is influenced by three types of variables: cognitive, affective, and situational. Cognitive variables refer to the mental structures that people use to formulate information needs and interpret information found. The affective variable refers to the feelings and emotional states of people. Situational variables provide the proper context for the information-seeking task (de Almeida et al., 2016, p. 1284).

The literature emphasizes that a properly developed CI allows you to achieve a number of benefits and solve numerous problems, such as (Shaitura, Ordov, Lesnichaya, Romanova, & Khachaturova, 2018, pp. 2–3):

- anticipate changes in the market,
- predict the actions of competition,
- identify new or potential competitors,
- draw conclusions based on the successes and mistakes of other companies,
- track information related to patents and licenses,
- assess the possibility of acquiring a new business,
- learn about new technologies, products and processes that may have an impact on the business,
- study political, legal and regulatory changes that could affect business,
- justify the need to start a new company,
- assess the business from the outside,
- help you use the latest business tools,
- transform the weaknesses of the enterprise into competitive advantages,
- detect changes and react before it’s too late,
- identify potential sources of information leakage,
- identify the weaknesses of competitors,
- collect information about partners and customers.

Moreover, research shows that companies operating in the market use CI primarily to achieve the following results (Calof & Wright, 2008, p. 723):

- new or increased revenue,
- new product or services,
- cost savings / avoidance,
- time savings,

- profit increases,
- financial goals met.

In particular, it can be observed that the information collected and processed with the use of CI is used in the decision-making process in such areas as (Calof & Wright, 2008, p. 724):

- corporate or business strategy,
- sales or business development,
- market entry decisions,
- product development,
- R&D / technology decisions,
- M&A decisions,
- due diligence,
- joint venture decisions,
- regulatory/legal responses.

This shows that CI affects a wide range of decision-making areas and is an important component in formulating a business strategy. It is difficult to identify any aspect of the organization's activities that would not benefit positively from the CI contribution (Calof & Wright, 2008, p. 724).

5.15. Statistical Process Control (SPC) and Computer-Aided Process Planning (CAPP)

The concept of "information management" defines a wide range of activities related to information resources, information flow management, technology and management in general. The behaviour of a person in the information society reflects the activity of the individual as a knowledgeable subject, his ability to navigate the information space. In information behaviour, the degree of accessibility and comfort of the use of aggregate information resources or, in other words, the opportunities that society provides to an individual who seeks to take place as a professional and personality is manifested. It's noted that information represents resources for human mental activity, which is the basis for the formation of new knowledge. This cannot be done without integration Statistical Process Control (SPC) and Computer-Aided Process Planning (CAPP).

Today there are five stages of information management (Figure 5.17). The first stage in the evolution of the necessary infrastructure for the integration of SPC and CAPP over the Internet was formed in the form of Web 0.0—Developing the Internet &Web 1.0 (1990–2000), when users only received information. SPC measures the outputs of processes, looking for small but statistically significant changes, so that corrections can be made before defects occur. SPC was first used within manufacturing, where it can greatly reduce waste due to rework and scrap.

It can be used for any process that has a measurable output and is now widely used in service industries and healthcare.

Web 1.0 was primarily used by companies and personal websites which only showed information (Loretz, 2017). This era empowered the common user with a few new concepts like blogs, social-media & video-streaming. Publishing your content is only a few clicks away! Few remarkable developments of Web 2.0 are Twitter, YouTube, Flickr and Facebook.

Figure 5.17. Stages of evolution of the World WEB in context information management SPC and CAPP

Source: Own study.

SPC became a key part of Toyota Production System and, by extension, lean manufacturing (Muelaner, 2019). However Basic Concepts of Process Routing Planning combined in Manufacturing of machining Processes. This stage contains generation of Principle of coincidence of references and factors causing machining errors of data, which improve of Methods for Technological References and Dimension Calculation and Recalculation of data (Wang & Li, 1991).

During the second stage Web 2.0 (2000–2006) users became participants in the generation and accumulation of statistics and were able to interact with each other (exchange information). Computer-Integrated Manufacturing has gained recognition as a most effective tool in increasing manufacturing competitiveness by activating of Computer-Aided Process Planning Systems knowledge (Wang & Li, 1991; Karpenko, Zhylinska, Zalizko, Kukhta, & Vikulova, 2019). Web 2.0 was the second stage or generation of the World Wide Web and it was known as "The Social Web" as users were able to not only read websites but also interact and connect with other users. All social media such as blogs, YouTube and many more emerged with Web 2.0 and companies realised the strength of community interaction with business websites. People were able to collaborate on ideas, share information and generate information that was available to whole world (Loretz, 2017).

The third stage Web 3.0 (2007–2011): development of large databases. Almost simultaneously with the third stage, the development of social networks and messengers began, which allowed the exchange of instant information—Web 4.0 (2009–2019). CAPP-system fully automates the planning of technological processes using computer programs. The most popular computer programs in the world should be divided according to the following rating: 1) WeldOffice (CAPP—CSPEC, USA); 2) WeldPlan (CAPP—Force Technology, Denmark). Simultaneously SPC-system uses statistical methods to monitor and control process using computer programs outputs. SPC must be carried out in two phases. The first phase ensures that the process is fit for purpose and establishes what it should look like. The second phase monitors the process to ensure that it continues to perform as it should. Determining correct monitoring frequency is important during the second phase and will in part depend on changes in significant factors, or influences (Muelaner, 2019). This means that Web 3.0 is not only a read and write web but also a web that focusses on the individual user and machine (Loretz, 2017). In this context, a computer program that is quite useful is the Statistical Package for the Social Sciences (SPSS). SPSS system allows you to choose from many options for regression analysis (linear regression, least squares analysis, polynomial regression, ordinal regression, etc.).

The fourth stage begin in 2020 (Web 4.0): construction of the Neuronet—networks where communication between people, animals and things will be based on the principles of neurocommunication, and the use of artificial intelligence. Thus, digital technologies have been the driving force of society for several decades, causing radical changes in the economy due to its digitalization. In the general interpretation of the European Commission, the digital economy is an economy based on the widespread use of digital technologies (European Commission, 2014). In context Web 4.0 & Web 5.0 Artificial Intelligence is the capacity of a computer to communicate, reason and behave just like a human, and this is exactly what, some believe, will be seen with web 4.0 and beyond. Web 4.0 or "The Intelligent Web" will exist between the years 2020 and 2030 and some believe it will be as intelligent as the human brain. From computers being personal assistants to virtual realities, holograms, all house appliances being connected to the Internet (Internet of Things) and implants to restore vision; highly intelligent interactions between machines and humans will occur (Loretz, 2017).

The five stage begin in 2020 (Web 5.0). This stage will integrate the three most important systems: economic, social, environmental through application of SPC, CAPP and blockchain. The algorithm Web 5.0 involves joint application of the computer (SPC&CAPP) to assist process planners. This opens up new planning functions define as Sustainable Statistical Process Control and Computer-Aided Process in context formatting of Information Management 5.0—the new competitive advantage of a new society of ideas and excellence. Let's highlight the main components SPC & CAPP contexting "The Telepathic Web" or "The Symbionet Web" will be present after the year 2030 and within this highly complex future web generation, some things such as brain implants will be very popular. Brain implants will give people, e.g., the ability to communicate with the Internet through thoughts, to think of a question and open up a web page (Figure 5.18).

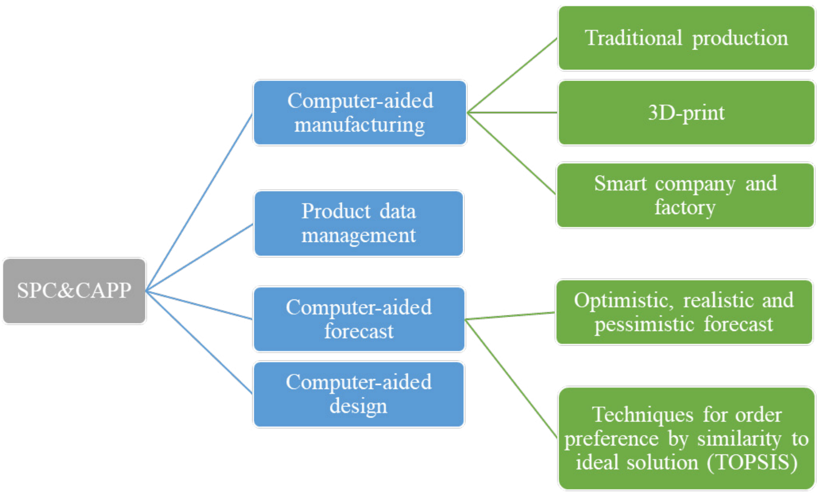

Figure 5.18. Systematization of structural elements SPC&CAPP

Source: Own study.

It allows scientifically grounded theoretical and methodological basis for the formation and implementation the strategy of Sustainable Statistical Process Control and Computer-Aided Process Planning in context formatting of Information Management. In this strategy considered as the key technology for integration of computer-aided design (CAD) and computer-aided manufacturing (CAM). This integration can be applied to machining e-tools, or to 3D printers for developing EU economical e-infrastructures.

A theoretical approach is substantiated to the formation of an innovative concept of Ukraine's economic security strengthening in the context of COVID-19, which provides for the formation of the gig-economic space as a new key driver of the national economy in the context of global epidemiological problems solving. An innovative system of weighted indicators of the economic security integral index is proposed. The proposals for the use of blockchain technologies make it possible to attract domestic public investment for training, soft loans and retraining of the economically active population in the amount of 1 billion dollars.

A theoretical approach to the formation of an innovative concept of Sustainable Statistical Process Control and Computer-Aided Process Planning strengthening in the context of COVID-19, which provides for the formation of Supply Chain Management (SCM) as a new key driver of EU economy. An innovative system of identification of suppliers, raw materials, components and logistics services and the proposals for the use of blockchain technologies make it possible to attract domestic public investment for training, soft loans and retraining of the economically active population in terms formatting of Information Society.

Presented of systematization of structural elements SPC & CAPP combines well with the proposed concept of strengthening the economic system on the example of Ukraine (Figure 5.19).

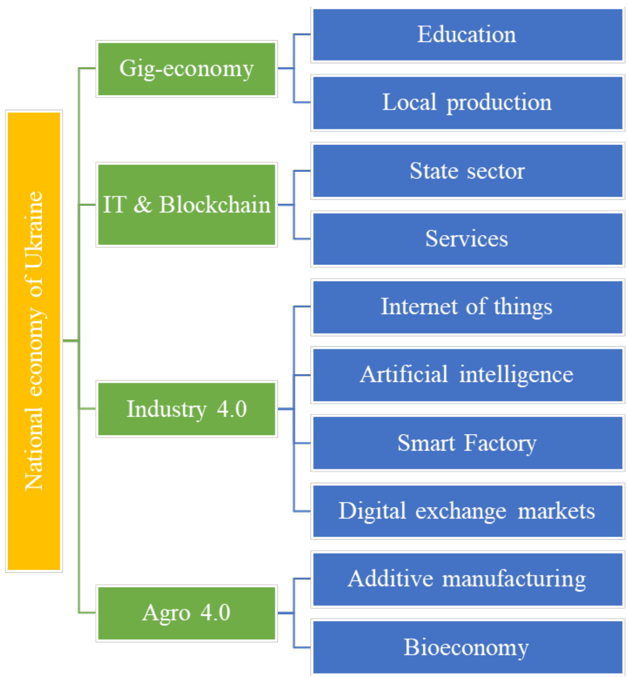

Figure 5.19. The concept of strengthening the economic system of Ukraine under the conditions of COVID-19

Source: (Zalizko, Nowak, & Kukhta, 2020).

From a practical point of view, it should be noted that SPC & CAPP systems are used mainly in the field of services (communications, consulting, etc.), but it is worth giving an example of the largest mining companies (Table 5.5).

Table 5.5. Ukrainian mining enterprises that use elements of SPC & CAPP system

Mining and Chemical Enterprise Polimineral in Stebnyk	Ukrainian Mining and Metallurgical Company PJSC
Marganets Mining and Processing Plant PJSC	United Mining and Chemical Company PJSC
SE Eastern Mining and Processing Plant	Mykolaiv alumina plant LLC
Boguslav Quarry, Open Joint-Stock Company	Druzhkivske Rudoupravlinnya PJSC
PJSC Kondrashivskyi Sand Quarry	Kremenchug Quarry Management Quartz PJSC
Northern Mining and Processing Plant PJSC	Central Mining and Processing Plant PJSC

Source: (Zalizko, Nowak, & Kukhta, 2020).

Presented of systematization of structural elements WEB 0.0–5.0 and SPC&CAPP combines well with the proposed concept of strengthening the strategy to stimulate the openness, strength and resilience of the EU's economic and financial system for the years to come. The outlined concept of strengthening the economic security in the context of the spread of acute respiratory disease COVID-19 caused by coronavirus SARS-CoV-2, provides for the institutionalization of gig-workers (freelancers), who must have not only tax benefits but also proper social, transport and information infrastructure (Zalizko, Nowak, & Kukhta, 2020).

Conclusions and suggestions. The outlined concept of strengthening the role of Sustainable Statistical Process Control and Computer-Aided Process Planning in context formatting of Information Management is important for minimization of the spread of acute respiratory disease COVID-19 caused by coronavirus SARS-CoV-2, as required provides for the institutionalization of remote CRM^{+-} system, which has the following functions:

1. Automatic enterprise resource planning and management.
2. Continuous acquisition and life cycle support.
3. Manufacturing requirement planning.
4. Planning the purchase of new goods, forecasting sales, analysis of marketing prospects, financial management, warehousing.
5. Automation of operational management tasks (manufacturing execution systems).
6. Remote execution of dispatching functions: collection and processing of data on the state of equipment, personnel safety, technological process (supervisory control and data acquisition).
7. Computer numerical control—mass installation of chips and controllers (specialized computers), which are built into the technological equipment with numerical software control (it is possible to use telephone sim-cards).
8. Automatic control of production life cycles in a single information space (product lifecycle management).

9. Distribution of income, payment of taxes, royalties and other payments on the principles of sustainable development of local areas.
10. Maintenance of a single information statistical database on gig-workers (freelancers).

These tasks must promote not only tax benefits but also proper social, transport and information infrastructure. First of all, we are talking about the potential innovative infrastructure of "Central European Network for Sustainable and Innovative Economy" that implements the synergistic effect of successful implementation of these proposals in local economic centers (united territorial community, rural areas, voivodships, megapolis, etc.) and must have proper social, ecological, transport and information infrastructure. This will help create an effective of Central European Network for Sustainable and Innovative Economy.

Questions / tasks

1. What is a production hall and what are its elements?
2. What is shop floor control?
3. What are the aims of shop floor control?
4. List and discuss the elements of Shop Floor Control.
5. What are the benefits of Shop Floor Control?
6. What is cooperative manufacturing?
7. What features of cooperation do you know?
8. What is reciprocity?
9. What is environment-conscious manufacturing (ECM) and life-cycle assessment (LCA)?
10. What is waste and what types of waste in an enterprise do you know?
11. How can company minimize waste in production-operation activities?
12. Discuss the diagram of the waste hierarchy.
13. Describe the Electronic Data Interchange process.
14. What advantages and disadvantages does the Electronic Data Interchange system have?
15. What are the differences and similarities between a real enterprise and a virtual enterprise?
16. Describe the virtual organization life-cycle model.
17. What advantages and disadvantages does the virtual enterprise method have?
18. What is World Class Manufacturing?
19. List the Pillars of Temple of WCM.
20. What advantages and disadvantages does the World Class Manufacturing method have?
21. What is the Quality Function Deployment method?

22. Describe the House of Quality diagram.
23. What are the stages of eliminating bottlenecks in theory of constraints?
24. What are the benefits of implementing the Drum Buffer Rope system?
25. What is cellular manufacturing?
26. What are the benefits of using group technology and cellular manufacturing?
27. What are the main differences between a traditional manufacturing system and a cell-based system?
28. What characterizes Demand Chain Management?
29. How does the organization acquire and process information?
30. How does the organization acquire and process information?
31. What are the benefits of having a properly developed competitive intelligence?
32. In which areas is competitive intelligence primarily used?
33. What is information management and what are its stages?
34. What are the CRM functions?

References

Alimian, M., Ghezavati, V., & Tavakkoli-Moghaddam, R. (2020). New integration of preventive maintenance and production planning with cell formation and group scheduling for dynamic cellular manufacturing systems. *Journal of Manufacturing Systems*, *56*, 341-358. https://doi.org/10.1016/j.jmsy.2020.06.011

Andersen, K. (1998). *EDI and data networking in the public sector*. https://doi.org/10.1007/978-1-4615-5487-5

Bacinschi, Z., Rizescu, C. Z., Stoina, E. V., & Necula, C. (2010). Waste management practices used in the attempt to protect the environment. In *Latest trends on engineering mechanics, structures, engineering geology: 3rd WSEAS International Conference on Engineering Mechanics, Structures, Engineering Geology* (EMESEG '10), International Conference on Geography and Geology (WORLDGEO '10).

Britannica. (n.d.). Retrieved November 2020 from https://www.britannica.com/science/recycling

Brzozowski, M. (2010). *Organizacja wirtualna*. Warszawa: PWE.

Burn, J., Marshall, P., & Barnett, M. (2001). *e-Business strategies for virtual organizations*. Oxford: Butterworth-Heinemann.

Byrne. (1993, February 8). The virtual corporation. *Business Week*, 98-103.

Calof, J., Arcos, R., & Sewdass, N. (2018). Competitive intelligence practices of European firms. *Technology Analysis & Strategic Management*, *30*(6), 658-671. https://doi.org/10.1080/09537325.2017.1337890

Calof, J. L., & Wright, S. (2008). Competitive intelligence: A practitioner, academic and inter-disciplinary perspective. *European Journal of Marketing*, *42*(7/8), 717-730. https://doi.org/10.1108/03090560810877114

Cittolin, S. F. (2018). Cooperation. A concept analysis. *Asian Journal of Business Management Studies*, *9*(2), 28-31.

Colak, G. D. (2004). *A distributed shop floor control system based on the principles of heterarchical control and multi agent paradigm*. (Unpublished doctoral dissertation). Massey University.

Cox, J., III, & Schleier, J. (2010). *Theory of constraints handbook*. New York: McGraw-Hill. Retrieved from http://125.234.102.146:8080/dspace/handle/DNULIB_52011/3161

Davidow, W. H., & Malone, M. S. (1992). *The virtual corporation: Structuring and revitalizing the corporation for the 21st century*. New York: HarperCollins.

de Almeida, F. C., Lesca, H., & Canton, A. W. P. (2016). Intrinsic motivation for knowledge sharing—competitive intelligence process in a telecom company. *Journal of Knowledge Management*, *20*(6), 1282-1301. https://doi.org/10.1108/JKM-02-2016-0083

Deepen, J. M., Goldsby, T. J., Knemeyer, A. M., & Wallenburg, S. M. (2008). Beyond expectation: An examination of logistics outsourcing goal achievement and goal exceedance. *Journal of Business Logistics*, *29*(2), 75-105.

Deshmukh, A. K., & Mohan, A. (2017). Analysis of Indian retail demand chain using total interpretive modeling. *Journal of Modelling in Management*, *12*(3), 322-348. https://doi.org/10.1108/JM2-12-2015-0101

Dudek, M. (2013). Zarządzanie rozwojem pracowników w systemach produkcji klasy światowej. *Zeszyty Naukowe. Organizacja i Zarządzanie, Politechnika Łódzka*, *50*. Retrieved December, 2020 from http://yadda.icm.edu.pl/baztech/element/bwmeta1.element.baztech-6e2de142-5cec-49d2--ad41-772a2f31bd48

Edison SA. (2020). *Podstawy EDI*. Retrieved December 15, 2020 from http://www.edi.pl

European Commission. (2014). *Report of the Commission Expert Group on Taxation of the Digital Economy*. Retrieved from https://ec.europa.eu/taxation_customs/sites/taxation/files/resources/documents/taxation/gen _info/good_governance_matters/digital/report_digital_economy.pdf

Fajczak-Kowalska, A. (2012) Wykorzystanie elektronicznej wymiany danych w wybranych przedsiębiorstwach. *Gospodarka w Praktyce i Teorii*, *31*(2), 27-41. Retrieved December, 20202 from http://yadda.icm.edu.pl/yadda/element/bwmeta1.element.hdl_11089_2398

Felice, F. D., Petrillo, A., & Monfreda, S. (2013). Improving operations performance with world class manufacturing technique: A case in automotive industry. *Operations Management*. https://doi.org/10.5772/54450

Frohlich, M. T., & Westbrook, R. (2002). Demand chain management in manufacturing and services: Web-based integration, drivers and performance. *Journal of Operations Management*, *20*(6), 729-745. https://doi.org/10.1016/S0272-6963(02)00037-2

Gajdzik, B. (2013). Jakość produktów jako filar produkcji klasy światowej. *Problemy Jakości*, *1*, 31-34.

Gartner Glossary. (n.d.). *Information technology*. Retrieved October, 2020 from https://www.gartner.com/en/information-technology

Goldratt, E. M. (1990). *What is this thing called theory of constraints and how should it be implemented?*. Great Barrington: North River Press.

Goldratt, E. M., & Cox, J. (2016). *The goal: A process of ongoing improvement*. London: Routledge.

Guide, V. D. R. (1996). Scheduling using drum-buffer-rope in a remanufacturing environment. *International Journal of Production Research*, *34*(4), 1081-1091. https://doi.org/10.1080/00207549608904951

Halevi, G. (2001). *Handbook of production management methods*. Oxford: Butterworth-Heinemann.

Hao, Q., Shen, W., & Wang, L. (2005). Towards a cooperative distributed manufacturing management framework. *Computers in Industry*, *56*, 71-84.

Heragu, S. S. (1994). Group technology and cellular manufacturing. *IEEE Transactions on Systems, Man, and Cybernetics*, *24*(2), 203-215. https://doi.org/10.1109/21.281420

Jacobsen, K. (2004). *A study of virtual organizations in mobile computing environments*. Trondheim: Norwegian University of Science and Technology Department of Computer and Information Science.

Jüttner, U., Christopher, M., & Baker, S. (2007). Demand chain management-integrating marketing and supply chain management. *Industrial Marketing Management*, *36*(3), 377-392. https://doi.org/10.1016/j.indmarman.2005.10.00

Kalisz, D., & Szyran-Resiak, A. (2018). Organizacja wirtualna w erze społeczeństwa informacyjnego. *Zeszyty Naukowe Państwowej Wyższej Szkoły Zawodowej w Płocku. Nauki Ekonomiczne*, *28*, 483-495. https://doi.org/10.19251/ne/2018.28(31)

Karpenko, L., Zhylinska, O., Zalizko, V., Kukhta, P., & Vikulova, A. (2019). Human development in the context of provision of the social safety of society. *Journal of Security and Sustainability Issues*, *8*(4), 1275-1286.

Keser, C., & van Winden, F. (2000). Conditional cooperation and voluntary contributions to public goods. *Scandinavian Journal of Economics*, *102*(1), 23-39.

Kisielnicki, J. (2001). *Zarządzanie organizacją: zarządzanie nie musi być trudne* (2nd ed.). Warszawa: Oficyna Wydawnicza Wyższej Szkoły Handlu i Prawa im. Ryszarda Łazarskiego.

Kisperska-Moroń, D. (2008). Świat wirtualnych organizacji. *Zeszyty Naukowe Wyższej Szkoły Zarządzania Ochroną Pracy w Katowicach*, *1*(4), 7-16.

Koch, L. T., Kautonen, T., & Grunhagen, M. (2006). Development of cooperation in new venture support networks: The role of key actors. *Journal of Small Business and Enterprise Development*, *13*(1), 62-72.

Kosmacz-Chodorowska, A. (2013). Elektroniczna wymiana danych dla przemysłu spożywczego. *Przemysł Spożywczy*, *11*, 18-21.

Kot, S., Starosta-Patyk, M., & Krzywda, D. (2009). *Zarządzanie łańcuchem dostaw*. Częstochowa: Wydawnictwo Wydziału Zarządzania Politechniki Częstochowskiej.

Kruczek, M., & Żebrucki, Z. (2012). Doskonalenie procesów utrzymania ruchu w przedsiębiorstwie branży hutniczej. *Logistyka*, *2*. Retrieved from http://yadda.icm.edu.pl/yadda/element/bwmeta1.element.baztech-article-BUS6-0040-0044

Loretz, C. (2017). *Social media networks in business*. Retrieved from https://carikesocial.wordpress.com/2017/03/15/the-world-wide-web-from-web-1-0-to-web-5-0/

Materna, L., Hinrichsen, S., Adrian, B., & Schulz, A. (2019). *How to improve shop floor management*. (9th International Conference Production Engineering and Management, Trieste, Italy, Conference paper).

Muelaner, J. (2019). *An introduction to Statistical Process Control (SPC)*. Retrieved from https://www.engineering.com/AdvancedManufacturing/ArticleID/19494/An-Introduction-to-Statistical--Process-Control-SPC.aspx.

Nowak, D. (2012). *Zarządzanie międzyorganizacyjnymi relacjami kooperacyjnymi w przedsiębiorstwach przemysłowych*. Poznań: Wydawnictwo Uniwersytetu Ekonomicznego w Poznaniu.

Piasecka-Głuszak, A. (2017). Implementacja World Class Manufacturing w przedsiębiorstwie produkcyjnym na rynku polskim. *Ekonomia XXI Wieku*, *4*(16), 52-65. Retrieved from https://doi.org/10.15611/e21.2017.4.04

Porter, M. E. (2001). Strategy and the Internet. *Harvard Business Review*, *79*(3). Retrieved from https://hbr.org/2001/03/strategy-and-the-internet

Random House Unabridged Dictionary. (1993). 2nd ed. New York: Random House.

Saabeel, W., Verduijn, T., Hagdorn, L., & Kumar, K. (2002). A model of virtual organization: A process and structure perspective. *Journal of Organizational Virtualness*, *4*(1), 1-16.

Sala, S., Reale, F., Cristobal-Garcia, J., Marelli, L., & Pant, R. (2016). *Life cycle assessment for the impact assessment of policies*. JRC Technical Reports, European Union.

Shaitura, S. V., Ordov, K. V., Lesnichaya, I. G., Romanova, Y. D., & Khachaturova, S. S. (2018). Services and mechanisms of competitive intelligence on the Internet. *Espacios*, *39*(45).

Shop Floor Control. (1997). *Process manufacturing*. Denver: J.D. Edwards World Source Company.

Shop Floor Management. (2017). *Tutorialspoint, simple easy learning*. Retrieved October, 2020 from https://www.tutorialspoint.com

Shujahat, M., Hussain, S., Javed, S., Malik, M. I., Thurasamy, R., & Ali, J. (2017). Strategic management model with lens of knowledge management and competitive intelligence: A review approach. *VINE Journal of Information and Knowledge Management Systems*, *47*(1), 55-93. https://doi.org/10.1108/VJIKMS-06-2016-0035

Sieber, P. (1999, September 23-24). *Organizational virtualness and electronic commerce*. Proceedings of the 2nd International VoNet-Workshop, Simowa.

Strader, T. J., Lin, F., & Shaw, M. J. (1998). Information strucuture for electronic virtual organization management. *Decision Support Systems. Decision Support Systems*, *23*, 75-94.

Telles, E. S., Lacerda, D. P., Morandi, M. I. W., & Piran, F. A. S. (2020). Drum-buffer-rope in an engineering-to-order system: An analysis of an aerospace manufacturer using data envelopment analysis (DEA). *International Journal of Production Economics*, *222*, 107500. https://doi.org/10.1016/j.ijpe.2019.09.021

Thürer, M., Stevenson, M., Silva, C., & Qu, T. (2017). Drum-buffer-rope and workload control in high-variety flow and job shops with bottlenecks: An assessment by simulation. *International Journal of Production Economics*, *188*, 116-127. https://doi.org/10.1016/j.ijpe.2017.03.025

Trojanowska, J., & Dostatni, E. (2017). Application of the theory of constraints for project management. *Management and Production Engineering Review*, *8*(3). https://doi.org/10.1515/mper-2017-0031

Vollmann, T., Cordon, C., & Heikkilä, J. (2000). Teaching supply chain management to business executives. *Production and Operations Management*, *9*, 81-90. https://doi.org/10.1111/j.1937-5956.2000.tb00325.x

Walczak, M. (2015). Dyfuzja produkcji w klasie światowej wewnątrz łańcucha tworzenia wartości (na przykładzie Fiat Auto Poland SA). *Przedsiębiorstwo i Region, Współpraca, Konkurencyjność, Rozwój*, *7*, 113- 122. https://doi.org/10.15584/pir.2015.7.12

Wang, H. P., & Li, J. K. (1991). *Computer-Aided Process Planning* (vol. 13). Amsterdam: Elseviere. Retrieved October, 2020 from https://www.elsevier.com/books/computer-aided-process-planning/wang/978-0-444-88631-6

Wemmerlöv, U., & Hyer, N. L. (1987). Research issues in cellular manufacturing. International *Journal of Production Research*, *25*(3), 413-431. https://doi.org/10.1080/00207548708919850

Wolniak, R. (2017). Koncepcja wykorzystania analizy Kano w metodzie QFD. In R. Knosala (Ed.), *Innowacje w zarządzaniu i inżynierii produkcji* (vol. 2, pp. 400-409). Opole: Oficyna Wydawnicza Polskiego Towarzystwa Zarządzania Produkcją.

Wolniak, R., & Sędek, A. (2008). Wykorzystanie metody QFD do projektowania proekologicznych produktów i usług. *Problemy Ekologii*, *12*(4), 179-182.

Yusuff, R. B. M., Vahabzadeh, A. H., & Panjehfouladgaran, H. (2012). *Environmental conscious manufacturing for sustainable growth*. (Conference Paper on International Seminar on Science and Technology Innovation). Retrieved November, 2020 from https://www.researchgate.net/publication/250002713_Environmental_Conscious_Manufacturing_for_Sustainable_Growth

Zalizko, V., Nowak, D., & Kukhta, P. (2020). Economic security of Ukraine: Innovative concept of strengthening in the context of Covid-19. *Scientific Bulletin of National Mining University*, *4*, 152-157.

Zimon, D., & Gawron-Zimon, Ł. (2014). Wykorzystanie metody QFD do doskonalenia logistycznej obsługi klienta. In R. Knosala (Ed.), *Innowacje w zarządzaniu i inżynierii produkcji* (vol. 1, pp. 1077-1078). Opole: Oficyna Wydawnicza Polskiego Towarzystwa Zarządzania Produkcją.

Zook, Ch., & Allen, J. (2005). *Strategia zrównoważonego wzrostu dla twojej firmy*, vol. 1: *Strategia wzrostu w erze turbulencji*. Gliwice: Bain and Company, Inc.