OPERATIONAL CONTROLLING IN THE MANAGEMENT OF SPARE PARTS AVAILABILITY

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Abstract

In order to meet the aimed financial result and market competitiveness, the management of a manufacturing enterprise's operating system and supply chain requires a system connection and the use of many tools, among others, financial and operational analysis, value management of processes and development of business models of cooperation with partners in the supply chain. Controlling assists result-oriented management and creates a subfunctional management system which supports management personnel in making decisions and creating mechanisms of efficient and effective management. The aim of the article is to determine the scope of use of the operating controlling system and its impact on the management of the availability of spare parts and the effectiveness of the production process. The article presents a system of indicators for assessing the efficiency of spare parts management in their supply chain as well as the results of empirical verification of the controlling system. The results of the research carried out by the Authors indicate that the process of maintenance and the availability of spare parts, especially in highly machinized, robotized and automatized production processes, is one of the most important factors in their continuity, failure recovery rate, and repair performance rate.

Keywords: operational controlling system, spare parts availability, production process efficiency

1. INTRODUCTION

In reference books on the continuity of production process, the authors revolve around research and analyses of production flow processes as production product and management of stock of finished goods, semi-finished products or raw materials. The issue of the availability of spare parts that safeguards the continuity of production resources is rarely addressed. The research results indicate that the process of maintenance and spare parts availability, especially in highly machinized, robotized and automatized production processes, is one of the most important factors in their continuity, failure recovery rate, and repair performance rate.

Numerous discussions on maintenance and service issues can be found in the reference books. According to ISO/TS 16949:2002 standard, the organization identifies the key equipment to run the process, provides resources for machine/ equipment maintenance and develops the effective planned system of full preventive maintenance. It is required that the system of operations of maintenance services includes (ISO/TS 16949:2002(E), p. 34):

- planned maintenance activities,
- packaging and protection of equipment, instrumentation and measuring devices,
- availability of spare parts for key production equipment,
- documenting, evaluating and improving service objectives.

With the development of scientific and technical knowledge and the complexity of machinery and equipment construction, as well as their electronization, automation and mechanization, there is a noticeable increase in the impact of faulty equipment on the maintenance of the continuity of the production process and the development of maintenance systems for equipment and machinery. The classic approach to managing maintenance in a production environment highlights the importance of inspections, maintenance, and repairs, while the new approach to maintenance focuses on the following issues (Legutko, 2009, p. 9-10):

- decision support tools: risk assessment, damage intensity models and analysis of their effects and expert systems,
- new maintenance techniques, e.g. state monitoring,
- changes in thinking about maintenance organization leading to joint participation and teamwork.

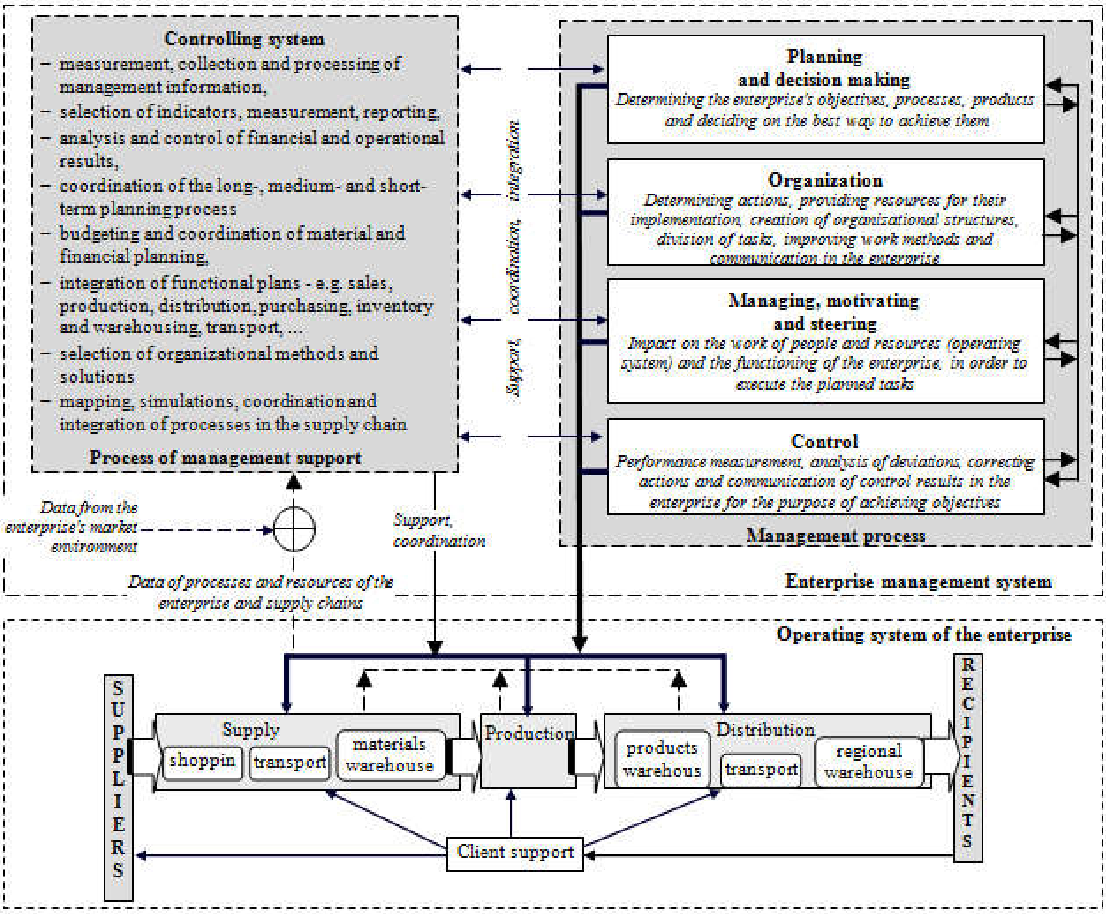
Therefore, it can be said that the development of the controlling system for spare parts availability management is a tool for supporting maintenance decisions, and in a broader process perspective, that it influences the effectiveness of the production process.

2. OPERATIONAL CONTROLLING IN ENSURING THE CONTINUITY OF MATERIAL FLOW

According to P. Drucker, the most important features of an enterprise management system include permanent and comprehensive monitoring and improving the efficiency of processes, focused on the basic and most important result, i.e. a client satisfied with the delivered product (Drucker, 2012). A system of strongly related factors of the operation of an enterprise – clients, products, processes, and resources – forms the scope and range of operational management (Christopher, Juttner & Godsel, 2006; Lambert, Knemeyer, Gardne, 2009; Waters, 2002). The results of long-term research (Śliwczyński, 2011; Franz, Kirchmer, 2012) on the adaptation of the enterprise management system to the changing market environment conditions point to a shift in the weight of the enterprise management towards the Score-Driven Management (SDM) model and the Value-Driven Business Process Management (VD BPM) model. Controlling is a tool that supports effective enterprise management in the conditions of a dynamically changing market. Logistics processes oriented towards ensuring material flow continuity in the supply chain are one of the key areas for applying operational controlling in an enterprise.

Controlling is a system that assists the management of an organization in achieving objectives (Fig. 1) by coordinating the processes of planning, organization, management and steering, controlling, as well as collecting and processing information (Sliwczynski, Kolinski, 2016).

Figure 1. The controlling system in the process of supporting decisions



Source: own study (Sliwczynski, Kolinski, 2016)

Controlling integrates and coordinates the following in an enterprise (Fig. 1):

- management functions – planning, organization, management and steering, control, response, and correction,
- activity areas – sales, distribution, manufacturing, purchasing and supply, marketing, research and development, customer service, warehousing and inventory, transportation, human resources management, outsourcing,

- management levels and stages of developing management decisions (strategic, tactical and operative) in the long, medium and short-term,
- value chains – integrating the needs of the market and the customer, products, processes and resources, as well as business performance (financial and operational), affecting the improvement of efficiency and eliminating waste (including bottlenecks).

The resulting management of information supports the decisions of selecting the methods and parameters of managing operations and resources in individual material flow phases, shaping the achieved results and value chain. Integration of all these elements is necessary to improve efficiency of logistics process. Integration is one of the most important of management style (Turkalj, Fosic, Dujak, 2008) and is successful tool in business practice.

Operational controlling is a system that assists operational management in achieving goals through the integration and coordination of planning, organization, steering, and control, as well as the collection and processing of information in relation to the product, processes and resources in the full supply chain (Śliwczyński, 2011).

The processes and resources shaped by controlling in the material flow are the result of the values of goals set for a manufacturing enterprise, its potential (production capacity), and the demands of (internal and external) clients, suppliers and subcontractors. Determining the methods of process management (e.g. purchasing and supplies, warehousing, transportation of spare parts) takes place already at the planning stage of operational measures and material flows in the supply chain. Continuous feedback taking into account the uncertain and variable demand for spare parts in production is the basis for correcting the plans, norms, methods, and parameters of process steering, resource allocation, designing of procedures and organizational structures, and budgets (material and financial plans). For this reason, the Authors focused their scientific research on the further development of an analysis of spare parts availability management within the controlling aspect.

3. MANAGEMENT OF SPARE PARTS AVAILABILITY WITHIN THE CONTROLLING ASPECT

The primary source of information needed to perform the controlling analysis of the management of spare parts availability is the linkage of the operating data associated with the flow of materials and the corresponding cost data recorded in the corporate chart of accounts. Data from the financial and accounting system make it possible to designate the economic indicators and measures within the scope of the spare parts availability model assessment system.

Based on the analysis of reference books (Pfohl, 2016; Sliwczynski, Kolinski, 2016; Twarog, 2003), a set of measures was determined, which was the basis for calculating the indicators for a controlling assessment of spare parts availability management.

Table 1. Set of indicators for a controlling assessment of spare parts availability management

Category	Indicator	Formula	Characteristics
Transport	costs of transport of a spare part from the supplier to the place of repair	$K_{T_{DN}} = l_d \cdot l_{km} \cdot k_{km} \cdot l_{ST} + l_d \cdot k_e$	l_d – number of deliveries in a given period between the supplier and the place of repair
			l_{km} – number of kilometers traveled by individual means of transport on the supplier–place of repair route in a given period
			k_{km} – cost of 1 kilometer for an individual means of transport on the supplier–place of repair route
			l_{ST} – number of individual means of transport used on the supplier–place of repair route in a given period
			k_e – cost of operation of the used means of transport on the supplie–place of repair route in a given period
	costs of transport of a spare part from the supplier to the warehouse in a given period	$K_{T_{DM}} = l_d \cdot l_{km} \cdot k_{km} \cdot l_{ST} + l_d \cdot k_e$	l_d – number of deliveries between the supplier and the warehouse in a given period
			l_{km} – number of kilometers traveled by individual means of transport on the supplier–warehouse route in the given period
			k_{km} – cost of 1 kilometer for an individual means of transport on the supplier–warehouse route
			l_{ST} – number of individual means of transport used on the supplier–warehouse route in a given period
			k_e – cost of operation of the used means of transport on the supplier–warehouse route in a given period
	costs of transport of a spare part from the warehouse to the place of repair in a given period	$K_{T_{MN}} = l_d \cdot l_{km} \cdot k_{km} \cdot l_{ST} + l_d \cdot k_e$	l_d – number of deliveries between the warehouse and the place of repair in a given period,
			l_{km} – number of kilometers traveled by the individual means of transport on the warehouse–place of repair route in a given period,
			k_{km} – cost of 1 kilometer for an individual means of transport on the warehouse–place of repair route,
			l_{ST} – number of individual means of transport used on the warehouse–place of repair route in a given period,
			k_e – cost of operation of the used means of transport on the warehouse–place of repair route in a given period,

Stock management	costs of maintenance of spare parts in stock	$K_{UT} = \mu \cdot Z \cdot c$	μ – cost factor of maintenance of spare parts in stock, Z – average volume of spare parts stock in a given period
Warehousing	costs of acceptance of a spare part	$K_P = l_P \cdot k_{jP}$	l_p – number of acceptances of spare parts in a given period k_{jp} – unit cost of acceptance of a spare part
	cost of a spare part storage in the warehouse	$K_{SK} = Z_{CZ} \cdot k_{jSK}$	Z_{cz} – size of spare part stock according to the accepted storage units (e.g. pallet places, m2, m3, etc.) K_{jSK} – unit cost according to the accepted storage unit
	costs of completion of a spare part	$K_K = l_K \cdot k_{jK}$	l_K – number of completed spare parts in a given period, k_{jK} – unit cost of completion of a spare part
	costs of release of a spare part	$K_W = l_W \cdot k_{jW}$	l_W – number of releases of spare parts in a given period, k_{jW} – unit cost of release of a spare part
Purchases	costs of placing an order for a spare part at the supplier's	$K_{Z_{CZ}} = k_{jZ_{CZ}} \cdot l_{Z_{CZ}}$	k_{jZCZ} – cost of one order associated with the purchase of a spare part l_{ZCZ} – number of placed orders for the purchase of a spare part in a given period
	costs of placing an order for a repair service at the supplier's	$K_{Z_U} = k_{jZ_U} \cdot l_{Z_U}$	k_{jZU} – cost of one order associated with the purchase of a repair service, l_{ZU} – number of placed orders for the purchase of repair services in a given period
	costs of placing an order for a spare part and a repair service at the supplier's	$K_{Z_{CZ-U}} = k_{jZ_{CZ-U}} \cdot l_{Z_{CZ-U}}$	k_{jZCZ-U} – cost of one order associated with the purchase of a spare part and a repair service, l_{ZCZ-U} – number of placed orders for the purchase of spare parts and repair services in a given period

Source: own study

In the case of transport organization by the supplier, this cost is determined by the supplier, whereas in the case of transport organization by an enterprise this cost is determined by:

– external company – if an enterprise subcontracts such a service, then the cost is determined by this company,
– enterprise – if the enterprise carries out the transport with its own rolling stock. In such a case, the cost components include: the number of kilometers to be traveled by a particular means of transport, the cost per 1 kilometer for a particular means of transport, the cost of operation of the used means of transport, the number of a particular means of transport, the number of deliveries.

An independent element of the spare parts availability management model is efficiency analysis. Efficiency analysis, based on the selected indicators, is becoming an increasingly popular area of analyses, related to financial results and used in enterprises. The research co-conducted within the operation of the Institute of Logistics and Warehousing in Poznan shows not only an increasing interest in analyses of the efficiency indicators of logistics processes but also the effectiveness of decisions made on their basis, as evidenced by the positive changes of indicator values in the annual observations[1]. Based on the analysis of the reference books (Hajdul, Kolinska, 2014; Kolinski, Sliwczynski, Golinska-Dawson, 2016; Krzyzaniak, 2015; Muchiri et al, 2011; Parida et al., 2015; Turkalj, Fosic, Dujak, 2010; Tsang, Jardine, Kolodny, 1999; Twarog, 2005; Stajniak, Kolinski, 2016) and conceptual works in research projects, [2,3,4] a set of indicators and measures was determined, which is presented in Table 2.

Table 2. Set of indicators and measures for the assessment of efficiency of spare parts availability management

Category	Indicator	Formula	Characteristics	Measure unit
Transport	supply reactivity index	$W_{RD} = \frac{l_{czPT}}{l_{cz}}$	l_{czPT} – number of spare parts delivered before deadline within the analyzed period,	%
			l_{cz} – number of spare parts delivered within the analyzed period	
	index of transportation demand	$W_{TR} = \frac{T_{TR}}{l_d}$	T_{TR} – transportation time within the analyzed period,	h/delivery
			l_d – number of deliveries within the analyzed period	
Stock management	coverage index	$W_P = \frac{Z}{W_Z} \cdot l_{dni}$	Z – average volume/value of the spare parts stock in the analyzed period,	days
			W_Z – volume/value of the consumption of spare parts in the analyzed period,	
			l_{dni} – number of days within the analyzed period	
	index of share of not rotating		Z_{NR} – value of not rotating spare parts stock,	%

[1] In the years 2008-2012, an analysis was conducted on the use of indicators at the global level. As of the second half of 2013, the analysis of the use of individual indicators and their impact on decisions was conducted using the Internet platform. The use of the Internet platform aimed to identify the trends of the indicators' changes, taking into account the specificity of individual industries and the possibility to compare individual values of indicators on benchmarking principles (Kolińska, Cudziło, 2014, p. 21-32).
[2] Development of a prototype of the Electronic Logistic Platform for handling enterprises using the 4PL/5PL concept, Institute of Logistics and Warehousing, Poznan 2007-2010.
[3] Simulation of managing the flow of a company's material as an instrument of multivariant analysis of transport processes efficiency no. N N509 549940, Poznań School of Logistics, Poznan 2011-2013.
[4] Development of methods and tools (including IT applications) supporting the analysis and improvement of enterprise logistics processes and supply chains – Platform development – benchmarking of indicators (LOGIBAR Platform), S-3737-4-2014, Institute of Logistics and Warehousing, Poznan 2014.

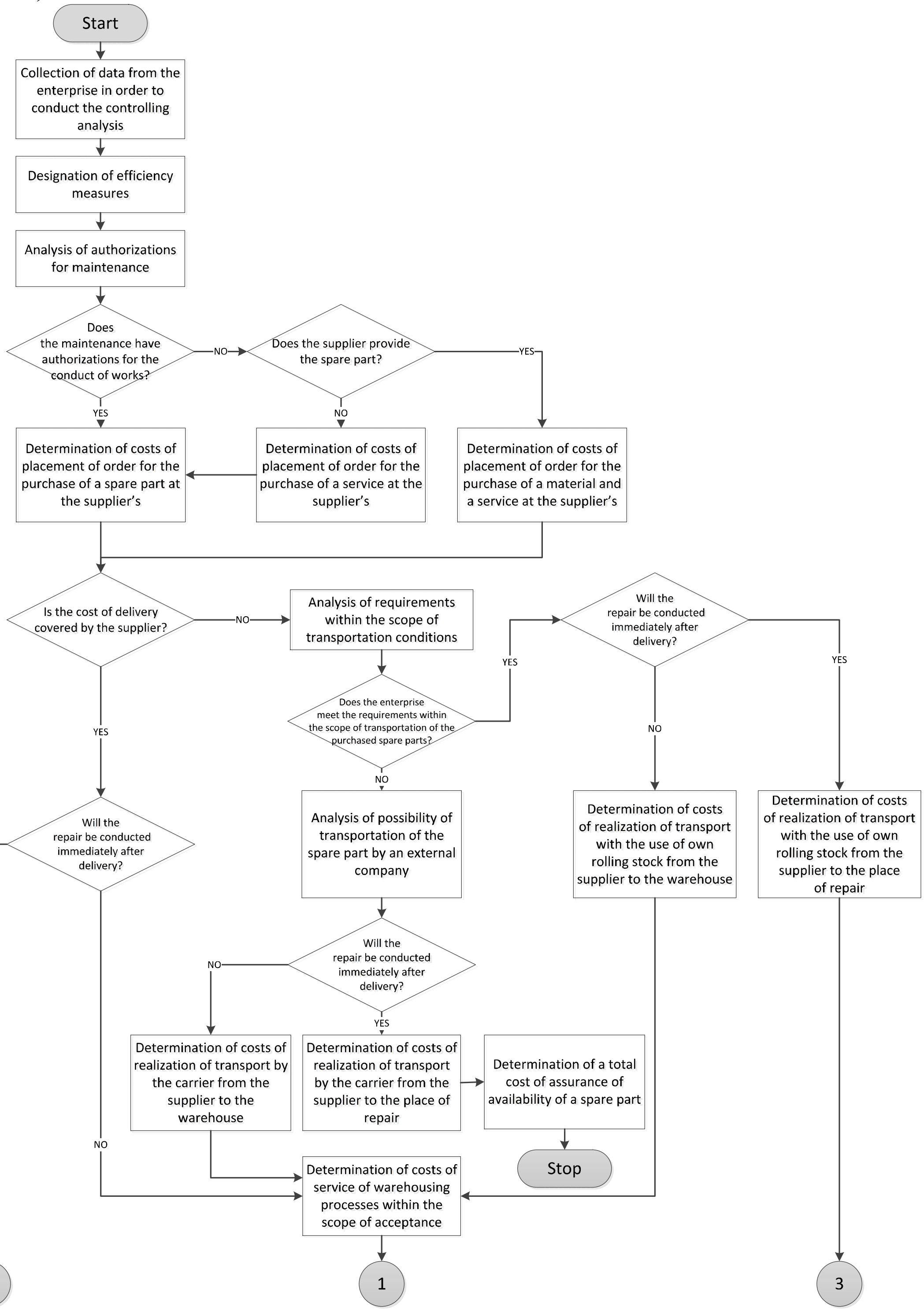
	stock in the stock	$W_{NR} = \frac{Z}{W_Z}$	Z_W – total value of spare parts stock	
Warehousing	warehouse employee work efficiency index	$W_{WM} = \frac{W_O}{l_{PR}}$	W_O – volume of turnover of spare parts stored within the analyzed period,	unit/person
			l_{PR} – number of employees in the warehouse within the analyzed period	
	index of labor intensity of the stored spare parts releases	$W_{PWM} = \frac{l_G}{W_W}$	l_G – number of warehouse employee's working hours within the analyzed period	-
			W_W – volume/value of stored spare parts releases within the analyzed period	
Purchases	index of timeliness of deliveries	$W_{TD} = \frac{l_{dt}}{l_d}$	l_{dt} – number of deliveries completed on time within the given period,	%
			l_d – number of deliveries in the given period	
	balance of completed orders	$W_{RZ} = \frac{C_d}{C_z}$	C_d – number of items of the given spare part delivered by the suppliers in the given period,	%
			C_z – number of spare part items ordered within this period	

Source: own study

This division has been developed analogically to the concept of the cost analysis of spare parts availability. In order to be able to compare the two elements of the model of spare parts availability management, it was decided to divide the indexes and measures of efficiency of activities associated with the assurance of production process continuity in terms of processes having a direct impact on production continuity (transport, storage, stock management, purchases).

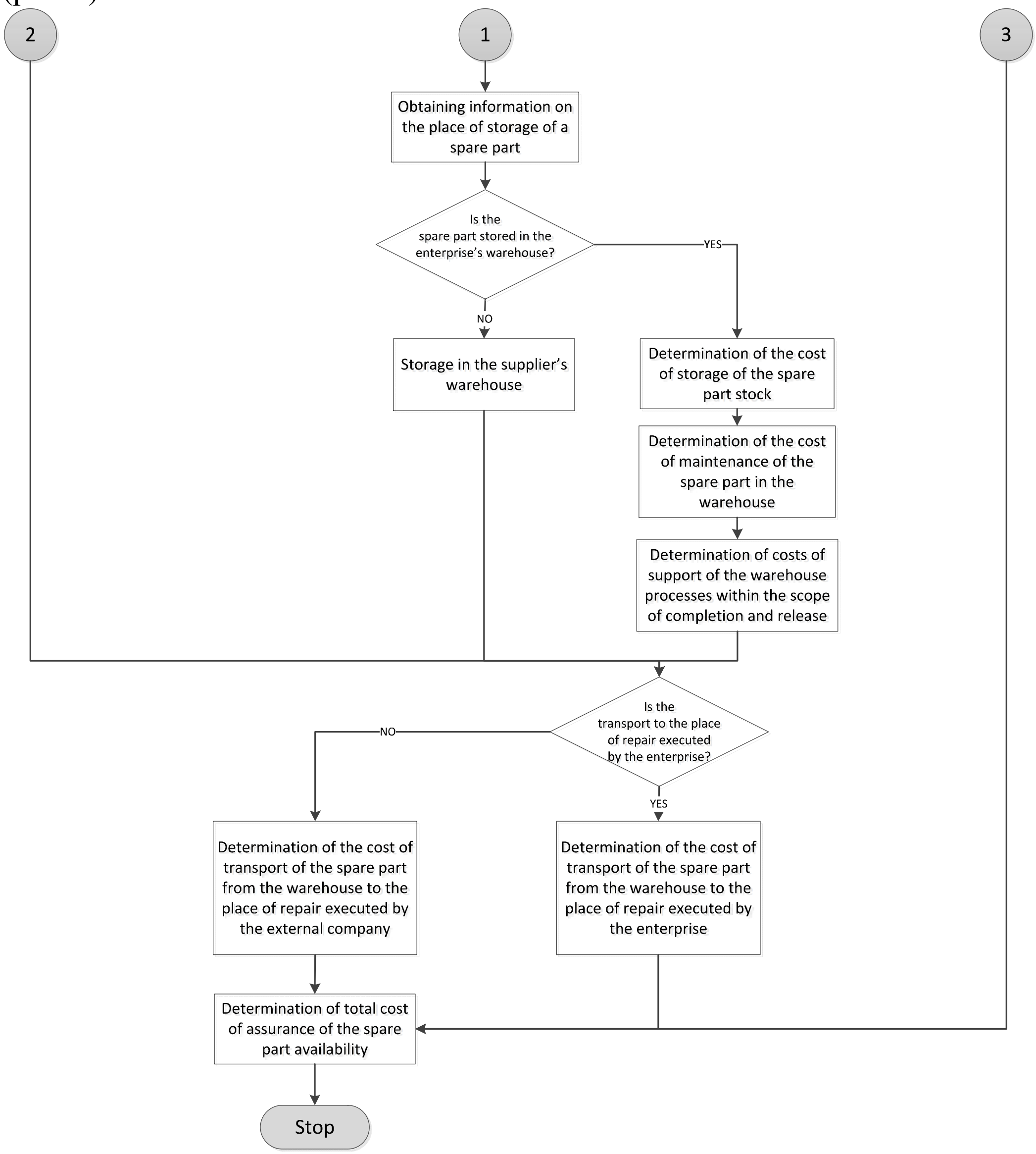
Taking into account the defined set of indexes and measures, the procedure algorithm (Fig. 2 and Fig. 3) has been developed, which enables to determine the costs incurred to ensure the availability of spare parts and the index-based assessment of spare parts availability assurance within the controlling aspect.

Figure 2. Algorithm for controlling analysis of spare parts availability assurance (part 1)



Source: own study

Figure 3. Algorithm for controlling analysis of spare parts availability assurance (part 2)



Source: own study

The total costs of spare parts availability assurance is the sum of costs of stock consumption incurred due to the implementation of this process. Depending on the course of this process, the elements making up the total costs of spare parts availability assurance vary.

4. METHODOLOGY OF EMPIRICAL VERIFICATION

Empirical verification is a process of determination of the extent to which the model faithfully reflects the actual system from the assumed point of view (Sargent, 2001). This aims at determining whether the simulation of the production environment provides reliable results, to the assumed extent in line with the responses of the actual system to identical input data. Thanks to verification, the model designer obtains information on its compliance with the assumptions adopted in the modeling process, and the validation based on the simulation of actual conditions verifies the compliance of the model operation according to the adopted assumptions in the actual conditions of the production process.

The analysis of the literature concerning the research methodology indicates that the research methods using the case study are not subject to evaluation of the test sample representativeness (Siggelkow, 2007, p. 21). Depending on the purpose of the conducted scientific research, the discussed method may take the form of an individual or multiplied case study. The individual case studies are aimed at confirming the theoretical assumptions, while the multiplied case studies enable to test the theory by comparing the cases with oneanother (Barratt et al., 2011, pp. 235-236). The multiplied case study is based on the selection of different or similar cases which aim at providing different or similar results respectively (Yin, 2009, p. 54).

When performing the analysis of the literature on the subject, one can find various opinions on the number of the conducted case study variants (Eisenhardt, Grabner, 2007, p. 27; Ketokivi, Choi, 2014, pp. 236-238; Tsang, 2014, pp. 178-182), which should be analyzed in order to obtain reliable conclusions of the validation test, and results which are reproducible and of a scientific nature. The dominating opinion suggests to conduct from four to ten variants of case studies (Eisenhardt, Grabner, 2007; Yin, 2009). Taking into account the specificity of spare parts availability management in manufacturing enterprises, the Authors stated that performing an empirical analysis for at least four variants of the case study will provide the validation of the developed model.

5. EMPIRICAL VERIFICATION OF THE CONTROLLING SYSTEM IN THE MANAGEMENT OF SPARE PARTS AVAILABILITY

In order to conduct the empirical verification, it was decided to adopt for analysis the spare part which was assessed as the critical one, from the point of view of assurance of production process continuity. Table 3 presents the detailed characteristics of the analyzed spare part.

Table 3. Spare part A characteristic A (A4 variant) adopted for the verification of the developed model

Criterion	Actual variant characteristic
Work mode	Unplanned
Group according to the criticality criterion	Critical
Groups according to the consumption frequency (123 classification)	1
Does the Maintenance have authorizations for execution of the repair using the given spare part?	Yes
Who bears the costs of delivery from the supplier to the enterprise?	Enterprise
Is equipment for the transport of a spare part from the supplier to the enterprise needed?	Yes
Does the enterprise have such equipment?	Yes

Who is responsible for the organization of the transport from the supplier to the enterprise and who implements it?	Enterprise
Is the time of preparation of the device for the repair longer than the time of delivery of a spare part?	No
Subject of the purchase	Material
Place of storage of spare parts	Enterprise
The owner of the spare part	Enterprise
Party responsible for making the decision on the volume and time of ordering the spare part	Enterprise
Will the spare part be used immediately after delivery to the enterprise?	No
Who performs the transport from the warehouse to the place of repair?	Enterprise

Source: own study based on data from a manufacturing enterprise

Presentation of the spare part specification was made in A4 variant, which is a reference variant, based on the real data obtained from the enterprise. Under the empirical verification using the case studies, the variants which differ in the adopted methods of supplementation of the spare part stock were used.

Performing the analysis of the costs of spare parts availability management, in the first step, required the collection of cost data (Table 4) and then determining the individual costs evaluating this area (Table 5).

Table 4. Data for determining the spare parts availability management costs

Variants		A0	A1	A2	A3	A4	A5
Cost of placing an order with the supplier for the purchase of a spare part	cost of one order associated with the purchase of a spare part	10.00	10.00	12.00	14.00	14.00	12.00
	number of placed orders for the purchase of a spare part	67.00	67.00	52.00	45.00	45.00	52.00
Cost of placing an order with the supplier for the purchase of a service	cost of one order associated with the purchase of a repair service	0.00	0.00	0.00	0.00	0.00	0.00
	number of placed orders for the purchase of a repair service	0.00	0.00	0.00	0.00	0.00	0.00
Cost of placing an order with the supplier for the purchase of a material and service	the sum of the cost of one order associated with the purchase of a spare part and a repair service	0.00	0.00	0.00	0.00	0.00	0.00
	number of placed orders for the purchase of a spare part along with a repair service	0.00	0.00	0.00	0.00	0.00	0.00
Costs of transport with own fleet from the supplier to the warehouse	number of deliveries	67.00	67.00	52.00	45.00	45.00	52.00
	number of kilometers to be traveled by the individual means of transport	220.00	220.00	220.00	220.00	220.00	220.00
	cost of 1 kilometer for the given means of transport	1.30	1.30	1.50	1.60	1.60	1.50
	cost of operation of the used means of transport	13,266.00	13,266.00	9,152.00	6,930.00	6,930.00	9,152.00
	number of individual means of transport	1.00	1.00	1.00	1.00	1.00	1.00
Costs of transport with own fleet from the supplier to the place of repair	number of deliveries	0.00	0.00	0.00	0.00	0.00	0.00
	number of kilometers to be traveled by the individual means of transport	0.00	0.00	0.00	0.00	0.00	0.00
	cost of 1 kilometer for the given means of transport	0.00	0.00	0.00	0.00	0.00	0.00

Variants		A0	A1	A2	A3	A4	A5
	cost of operation of the used means of transport	0.00	0.00	0.00	0.00	0.00	0.00
	number of individual means of transport	0.00	0.00	0.00	0.00	0.00	0.00
Costs of transport by the carrier from the supplier to the warehouse		0.00	0.00	0.00	0.00	0.00	0.00
Costs of transport by the carrier from the supplier to the place of repair		0.00	0.00	0.00	0.00	0.00	0.00
Costs of transport of a spare part from the warehouse to the place of repair executed by the external company	number of deliveries (number of warehouse releases)	0.00	0.00	0.00	0.00	0.00	0.00
	Costs of transport of one delivery of the spare part from the warehouse to the place of repair executed by the external company	0.00	0.00	0.00	0.00	0.00	0.00
Costs of transport of a spare part from the warehouse to the place of repair executed by the enterprise	number of deliveries (number of warehouse releases)	61.00	61.00	61.00	61.00	61.00	61.00
	number of kilometers to be traveled by the individual means of transport	6.00	6.00	6.00	6.00	6.00	6.00
	cost of 1 kilometer for the given means of transport	1.40	1.40	1.40	1.40	1.40	1.40
	cost of operation of the used means of transport	311.10	311.10	311.10	311.10	311.10	311.10
	number of individual means of transport	1.00	1.00	1.00	1.00	1.00	1.00
Cost of support of warehouse processes within the scope of acceptance	number of the given spare part accepted to the warehouse (results from the volume of acceptances)	300.00	300.00	300.00	300.00	300.00	300.00
	unit cost of acceptance of the given spare part	1.39	1.39	1.25	1.10	1.10	1.25
Cost of storage of the spare part stock	average volume of the spare part stock stored in the warehouse	29.00	29.00	30.00	31.00	30.00	24.00
	unit cost of storage of the given spare part	3.33	3.33	3.33	3.33	3.33	3.33
Cost of support of warehouse processes within the scope of completion	the number of spare part subject to completion	268.00	268.00	268.00	268.00	268.00	268.00
	unit cost of completion of the given spare part	2.08	2.08	2.08	2.08	2.08	2.08
Cost of support of warehouse processes within the scope of release	the number of the given spare part released from the warehouse (results from the volume of releases)	268.00	268.00	268.00	268.00	268.00	268.00
	unit cost of release of the given spare part	1.25	1.25	1.25	1.25	1.25	1.25
Cost of spare part maintenance in the warehouse		22,555.32	5,914.14	5,914.14	6,118.08	6,322.02	6,118.08
Price of spare part purchase		1,019.68	1019.68	1019.68	1019.68	1019.68	1019.68

Source: own study based on data from a manufacturing enterprise

Table 5. Costs of management of spare part availability in the individual variants

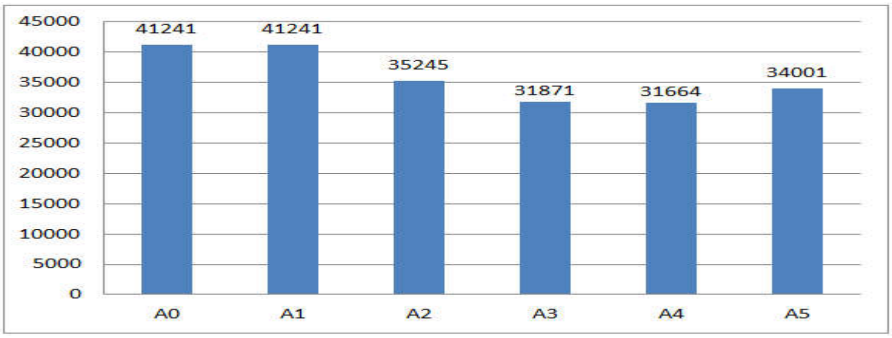
Variants	A0	A1	A2	A3	A4	A5
Cost of placing an order with the supplier for the purchase of a spare part	670	670	624	630	630	624
Cost of placing an order with the supplier for the purchase of a service	0	0	0	0	0	0
Cost of placing an order with the supplier for the purchase of a material and service	0	0	0	0	0	0

Costs of transport with own fleet from the supplier to the warehouse	32428	32428	26312	22770	22770	26312
Costs of transport with own fleet from the supplier to the place of repair	0	0	0	0	0	0
Costs of transport by the carrier from the supplier to the warehouse	0	0	0	0	0	0
Costs of transport by the carrier from the supplier to the place of repair	0	0	0	0	0	0
Costs of transport of a spare part from the warehouse to the place of repair executed by the external company	0	0	0	0	0	0
Costs of transport of a spare part from the warehouse to the place of repair executed by the enterprise	824	824	824	824	824	824
Cost of support of warehouse processes within the scope of acceptance	417	417	375	330	330	375
Cost of storage of the spare part stock	97	97	100	103	100	80
Cost of support of warehouse processes within the scope of completion	557	557	557	557	557	557
Cost of support of warehouse processes within the scope of release	335	335	335	335	335	335
Cost of spare part maintenance in the warehouse	5914	5914	6118	6322	6118	4894
Total cost of assurance of spare part availability	**41241**	**41241**	**35245**	**31871**	**31664**	**34001**

Source: own study based on data from a manufacturing enterprise

In order to interpret the results, the variants which differ by the adopted methods of supplementation of spare parts stock were selected (Fig. 4).

Figure 4. The annual total costs of management of spare part availability in the individual variants



Source: own study

Under the analyzed group of variants, the lowest total costs were achieved by A4 variant, so the recommended one. Therefore, it can be concluded that the selected method of spare parts stock supplementation is appropriate for the given spare part with the remaining criteria assumed.

The factor supplementing the controlling analysis is the evaluation of the efficiency of spare part availability management using the developed system of indexes. For this purpose, for validation of the model, the additional operational data, necessary for effective evaluation of the efficiency of the analyzed process were used.

Data necessary for performing the analysis of the efficiency of spare part availability management come from the manufacturing enterprise and are presented in Table 6.

Table 6. Input data for the analysis of the efficiency of spare parts availability management

Variants		A0	A1	A2	A3	A4	A5
Reactivity of delivery (W1)	number of spare parts delivered before the deadline	10	10	12	10	10	12
	total number of the delivered spare parts	268	268	268	268	268	268
Index of transportation demand (W2)	transportation time	29	29	24	18	18	24
	total number of deliveries	67	67	52	45	45	52
Warehouseman work efficiency index (W3)	volume of turnover of spare parts stored within the given period	268	268	268	268	268	268
	average number of employees in the warehouse	1	1	1	1	1	1
Index of labor intensity of the stored spare parts releases (W4)	number of warehouse employee's working hours within the given period	0.27	0.27	0.27	0.27	0.27	0.27
	volume of releases of the stored spare parts	268	268	268	268	268	268
Coverage ratio (W5)	average spare parts stock in a given period	29	29	30	31	30	24
	volume of consumption of spare parts in a given period	268	268	268	268	268	268
	number of days in a given period	365	365	365	365	365	365
Index of share of not rotating stock in the stock (W6)	value of not rotating spare parts stock	0	0	0	0	0	0
	total value of spare parts stock	29571	29571	30590	31610	30590	24472
Index of timeliness of deliveries (W7)	number of deliveries executed on time	67	67	52	45	45	52
	total number of deliveries in a given period	67	67	52	45	45	52
Balance of completed orders (W8)	number of units of a particular spare part delivered by the suppliers in a given period	300	300	300	300	300	300
	total number of units of a spare part ordered in this period	300	300	300	300	300	300

Source: own study based on data from a manufacturing enterprise

Due to the fact that measures of particular indicators also concern various material flow processes, which directly affect the continuity of the production process, all the designated indicators are considered equivalent.

In order to evaluate the efficiency, a score comparison method was developed for individual results of efficiency analysis. The scale of obtained points was determined on the basis of the hierarchy of results obtained from a given indicator. Table 7 presents a scoring scale for particular places in the hierarchy.

Table 7. Scoring scale

I place	II place	III place	IV place	V place	VI place
10 points	8 points	6 points	4 points	2 points	0 points

Source: own study

Summary of results for individual indicators and ranking of variants (total points obtained by the analyzed variants) are presented in Table 8.

Table 8. Results of efficiency assessment

	Results of efficiency analysis								**Points obtained according to the scale**								**Total**
	W1	W2	W3	W4	W5	W6	W7	W8	W1	W2	W3	W4	W5	W6	W7	W8	
A0	3.73%	0.43	268	0.001	39	0%	100%	100%	8	8	10	10	8	10	10	10	**74**
A1	3.73%	0.43	268	0.001	39	0%	100%	100%	8	8	10	10	8	10	10	10	**74**
A2	4.31%	0.46	268	0.001	41	0%	100%	100%	10	6	10	10	10	10	10	10	**76**
A3	3.73%	0.40	268	0.001	42	0%	100%	100%	8	10	10	10	10	10	10	10	**78**
A4	3.73%	0.40	268	0.001	41	0%	100%	100%	8	10	10	10	10	10	10	10	**78**
A5	4.31%	0.46	268	0.001	33	0%	100%	100%	10	6	10	10	6	10	10	10	**72**

Source: own study based on data from a manufacturing enterprise

The presented results of total costs and the assessments of the efficiency of providing spare parts availability confirm that the most reasonable solution is A4 variant, i.e. the variant indicated by the controlling system (in a limited space for the consideration of variants – the quasi-optimum variant). Therefore, this analysis confirms the correctness of the logic of the developed controlling system for managing the availability of spare parts.

6. CONCLUSION

The issue of the availability of spare parts is an important element of the efficient management of a production enterprise that requires in-depth analysis and research. There is no unequivocal solution in the current scientific work on the scope and method of analyzing the availability of spare parts in terms of maintenance of continuity of the production process. The lack of a defined method of comprehensive network analysis of factors influencing the spare parts availability management process prevents making proper decisions in this regard. Research conducted by the Authors confirm the need to implement three basic elements within the comprehensive analysis of spare parts availability: analysis of securing the needs of production continuity, analysis of the selection of methods of spare parts' completion and controlling analysis. In this article, the Authors focused only on the third element that enables the assessment of the effectiveness of spare parts availability management.

The validation procedure conducted using case studies of 6 variants confirms the complexity of managing the availability of spare parts to ensure continuity of the production process. Using the case-study-based research method, a multidimensional analysis was carried out, which allowed to verify the defined variants. The empirical research discussed in this article also confirms the possibility of using the developed tool in a spreadsheet to conduct prognostic analyses of efficient assurance of the availability of spare parts in the production process.

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