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## THE RESULTS OF THE STUDY CONCERNING THE IDENTIFICATION OF THE ACTIVITIES REALIZED IN THE MANAGEMENT OF THE TECHNICAL INFRASTRUCTURE IN LARGE ENTERPRISES

### WYNIKI BADAŃ DOTYCZĄCYCH IDENTYFIKACJI DZIAŁAŃ REALIZOWANYCH W ZARZĄDZANIU INFRASTRUKTURĄ TECHNICZNĄ W DUŻYCH PRZEDSIĘBIORSTWACH\*

*The activities realized within the technical infrastructure supervision are particularly important for large enterprises. It's commonly believed that in large enterprises there is a wide range of tasks realized within the technical infrastructure supervision. The studies done so far indicate only the machine supervision strategies used in enterprises, yet it doesn't indicate what activities are specifically realized. In fact, in spite of the rules adopted for each strategy, they are not used entirely in practice. The aim of the survey, of which the results are presented in this paper, was to identify the real activities conducted in enterprises within the technical infrastructure supervision in large enterprises. The survey concerned production enterprises functioning in different industries on a specified area. The results were drawn up and presented graphically. The results indicate both the activities which are commonly realized and those which are rare in this group of enterprises.*

**Keywords:** large enterprises, machines, maintenance, management, survey.

*Działania realizowane w zakresie nadzoru nad infrastrukturą techniczną są szczególnie istotne dla dużych przedsiębiorstw. Powszechnie panuje przekonanie, że w dużych przedsiębiorstwach istnieje duży zakres zadań realizowanych w ramach nadzoru nad infrastrukturą techniczną. Dotychczas przeprowadzone badania wskazują jedynie na stosowane w przedsiębiorstwach strategie nadzoru nad maszynami, jednakże nie wskazuje się, jakie działania są konkretnie realizowane. W rzeczywistości mimo zasad przyjętych dla każdej strategii w praktyce nie są one tak do końca stosowane. Celem badań, których wyniki przedstawiono w niniejszej pracy, było zidentyfikowanie rzeczywistych działań, które są prowadzone w przedsiębiorstwach w zakresie nadzoru nad infrastrukturą techniczną w dużych przedsiębiorstwach. Badania dotyczyły przedsiębiorstw produkcyjnych funkcjonujących w różnych branżach przemysłu na określonym obszarze. Wyniki badań opracowano i przedstawiono w postaci graficznej. Wyniki badań wskazują zarówno na te działania, które są powszechnie realizowane, jak i na te, które rzadko występują w tej grupie przedsiębiorstw.*

**Słowa kluczowe:** ankietyzacja, duże przedsiębiorstwa, maszyny, utrzymanie ruchu, zarządzanie.

#### 1. Introduction

The technical condition of the technical infrastructure owned influences substantially the quality level of the product and the final competitiveness of the enterprise. This issue is particularly important in large enterprises where the sudden production interruptions caused by unexpected failures incur huge financial losses of the enterprises [21, 25]. The failures may cause sudden changes of the processing parameters, and, in consequence, in the production of the parts that don't meet the quality requirements, what increases the production costs. Additionally, it may generate costs connected with the failure to meet the deadlines of the contracts concluded. There are also obviously repair costs. That is why an important task of the managers of these enterprises is forming a proper level of exploitation efficiency of the technical infrastructure owned through the realization of the proper activities.

The research done so far is limited to the identification or indication of the machine supervision strategies [28, 33]. The way of their matching and incorporating into an organization's strategies was analysed [3, 24]. The research related to the identification and assessment

of policy used by the enterprises on the technical infrastructure supervision was carried out [31, 34], and in the paper [30] the examples of the development of the strategies used were presented.

Whereas, in the paper [4] the authors point to the necessity of the personnel participation in the maintenance program. In another, paper [22] the framework for using the modern strategy of RBM (risk-based maintenance) is presented. The suggestions of the application of new approaches into the technical infrastructure supervision [5], as well as models of decision processes support in using particular strategies [1, 10] also appear.

Different models of the optimization of activities related to the machine maintenance [23] and also indicators for the machine supervision assessment [16] were demonstrated, or the ones used in practice were identified by means of a questionnaire [18]. In the paper [26] a literature review for the indicators used in the machine efficiency assessment in the industrial sector was presented.

However, it is difficult to find any study indicating what activities are realized by enterprises in reality. E.g. in the paper [12] the results of the study ran in the Czech agro-industrial enterprises were shown, but the emphasis was put on the IT systems used. Likewise, in the

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paper [11] computer systems supporting machine supervision strategies were described.

The authors found the study of which the results were presented in the paper [29]. The authors of this paper analysed five large companies but only for the applied condition-based maintenance strategy. Then, in paper [2] the results of the study ran in the Swedish enterprises were presented. Among others, the most willingly used strategies were indicated.

The results of the research conducted in small and medium enterprises are available. They aimed at identifying the factors which influence taking decisions on the maintenance strategy improvement [7]. And the paper [8] classifies the tools used in the machine supervision with regard to the quantitative and qualitative division.

The known strategies of the technical infrastructure management point to the activities which should be performed, however the reality may differ.

In this article, the typical machine supervision strategies were reviewed and the actions that should be realized within the particular strategies were indicated, and then, it was checked if these actions are actually realized in practice.

Next, the results of the survey conducted in the chosen large enterprises located in the limited geographical area (Poland, podkarpackie province) were presented. The survey concerned the identification of actions realized in the technical infrastructure management, with a particular focus on the organization and realization of the preventive activities of the maintenance services.

## 2. A review of the machine supervision strategies and the actions performed within them

### 2.1. Development of the machine supervision strategies

Organizing a production system, particularly a set of machines and appliances, its usage and reorganization or liquidation is connected to a specific exploitation strategy and with the implementation of the appropriate management methods.

The analysis of the approaches to the machine and appliances performance maintenance, done in a period of time, allows distinguishing three periods which evolve into one another [15, 17, 19, 20]:

- I The period of reactive maintenance – the repairs are done after the failure appears (Corrective Maintenance), in other words, it is emergency maintenance. It means that the employees wait till the failure appears and then they attempt to remove it.
- II The period of preventive maintenance – planned preventive repairs – a strategy according to the exploitation potential (Scheduled Maintenance).
- III The period of the predictive (proactive) maintenance – preventive inspections, technical condition monitoring, participation of the machine and appliances operators in the maintenance (a strategy according to the condition - Condition Based Maintenance, according to reliability – Reliability Centered Maintenance and TPM – Total Productive Maintenance).

In an enterprise, several of them are used at the same time; however one dominant can often be distinguished.

### 2.2. Corrective Maintenance

The approach to failures is a typical example of a reactive approach in the machine maintenance. Running machines till the moment of the increased intensity of the machine or appliance's failures is the characteristic of this strategy. The most often used within this strategy is a method of corrective maintenance which means that maintenance is carried out only after the failure, that causes a loss of operational condition, occurred. The scope of corrective maintenance

is determined on the basis of the inspection done after the failure occurred, and it includes the measures and activities which assure the object's restoration to its operational condition. This method is used only for the machines and appliances where the failure aftereffects don't cause risks, don't violate the rules of work safety and don't increase the exploitation costs [9, 13].

### 2.3. Scheduled Maintenance

This approach, often called a system of preventive and repair works, is one of the most efficient methods of technological machines park management. The main determinant of its use is the exploitation life (a resource set). It is one of the important determinants of the exploitation quality of mechanical objects in exploitation theory and practice. A service life is a measure of the object's ability to perform its distinguished kinds of usage. For every mechanical object such a work life may be determined and expressed by e.g. a number of working hours after which it requires specific technical service (TS1, TS2,...) or replacement. For the proper (optimal) work of the object, it is crucial to determine the values of inter-service life, or periodical service and its extent [6, 9, 13].

### 2.4. Condition Based Maintenance

The condition based approach involves the control of the machines technical condition as well as formulating diagnostic information on that basis, what enables taking effective decisions in the exploitation system and its environment. We can distinguish two ways of the technical condition assessment: continuous (monitoring the system) or periodic, in the chosen periods of time, with different periods between the subsequent assessments [13, 14]. Due to this approach, it is possible to run a machine almost to the very moment of its failure. This solution is economically beneficial as well [15, 32].

The process of continuous monitoring has a lot of advantages: extended service intervals (increased performance and lower repair costs), real increased elimination of unexpected failures (increased reliability, and, consequently, performance as well), elimination of consequent damages (e.g. a simple bearing damage ends with a transmission gear damage), elimination of component losses (irreparable parts don't have to be replaced), reduction of a spare part warehouse (the method indicates the required spare parts), shortening of the repair time (planning the necessary operations) [6].

### 2.5. Mixed approach

In practice, it is common to comprise a partially fixed schedule and a continuous or periodic diagnostics [27, 32].

### 2.6. Actions taken within particular strategies of the machine supervision

Table 1 shows actions imposed by applying a particular strategy of the machine supervision. These actions have been divided into the ones performed by maintenance services, an operator or automatically. Additionally, tools supporting the proper strategy have been determined.

The actions presented should be performed while applying a particular strategy. However, based on the authors' experience, it is not always the case. Therefore, the decision to carry out the survey presented in this paper.

## 3. Survey subject and methodology

The actions identified and presented in Table 1 were verified by the survey on the technical infrastructure supervision carried out in large enterprises. The survey regarded production enterprises from different industries on a specified area. As a detailed subject of the

Table 1. Actions taken for the particular strategies of technical infrastructure management

Supervision strategy	Actions performed by maintenance services	Actions performed by an operator	Actions performed automatically	Use of additional tools
Exploitation potential based (Scheduled Maintenance, Preventive Maintenance) <b>PM</b>	Machine maintenance, inspections and repairs according to the number of the hours worked	Reporting the machine incorrect operation	Recording the machine working time	Machine work schedule
Potential condition based (Condition Based Maintenance) <b>CBM</b>	Analysis of the machines technical condition and continuous monitoring of their condition	Regular analysis of the technical condition, reporting the machine incorrect operation	Collection and analysis of the data considering technical parameters of the machine (e.g. vibrations, noise, processing accuracy)	Analysis of vibrations noise, temperature, vibrations, etc.
Efficiency based (Corrective Maintenance) <b>CM</b>	Regular failure removal, identification of the failure causes and its maintenance	Reporting the machine incorrect operation	Recording irregularities	-
Mixed Strategy <b>MS</b>	Machine maintenance, inspections and repairs according to the number of the hours worked, machines technical condition analysis, continuous monitoring of the machines condition	Regular analysis of the technical condition, reporting the machine incorrect operation	Recording the machine working time, collection and analysis of the data considering technical parameters of the machine (e.g. vibrations, noise, processing accuracy)	Machine work schedule. Analysis of vibrations noise, temperature, vibrations, etc.
Outsourcing <b>O</b>	None – performed by external services	Regular analysis of the technical condition	-	-

Table 2. The areas of the infrastructure management covered by the survey

It. No.	Area of infrastructure management	Element of infrastructure management being studied
1.	Ways of technological machines supervision	<ul style="list-style-type: none"> <li>The kind and scope of the tasks performed</li> <li>The responsible for the machine supervision</li> </ul>
2.	Kinds of information regarding the machines collected in enterprises	<ul style="list-style-type: none"> <li>Kinds of downtime present in a company</li> <li>Information collected</li> <li>People responsible for collecting information</li> <li>The way of recording information</li> </ul>
3.	Actions taken in order to minimize unexpected machine downtimes	<ul style="list-style-type: none"> <li>The kind of action undertaken</li> </ul>

survey, the areas of the enterprise infrastructure management described in the Table 2 were analysed.

In the area surveyed (podkarpackie province), in 2010 when the research started, there were 152 618 enterprises registered, including 202 large ones (data from the Marshal's Office of podkarpackie province, Department of Strategy and Planning). During the survey of the enterprises, the following categories for population identification were adopted: business and production types. 150 enterprises were invited to take part in the survey. Any enterprise, plant or its department that had its own strategy and accounted of its accomplishments could be the object of the survey. 46 questionnaires were obtained as a feedback.

The survey took the form of interviews. The subjects of the survey were the representatives of a medium and top level management as well as the employees directly responsible for the process of technological machines and appliances supervision in a company, and also chosen machine operators. The surveys were conducted in a conjunctive multiple choice format, and included a list of prepared, provided in advance options presented to a respondent with a multiple response item in which more than one answer might be chosen. Additionally, one could give other answers if they were not among the provided options.

#### 4. The structure of the surveyed enterprises

During the survey, the enterprises were classified according to the following criteria: business type, production type, ownership (type of capital) and technical infrastructure organization.

Most companies, as many as 42% (Fig. 1), were aviation companies and 34% were automotive companies. The remaining business types included among others metal processing, chemical, wood and paper, and food industry.

Figure 2 shows the structure of the enterprises surveyed according to the production type. Among the surveyed enterprises most were the organizations with

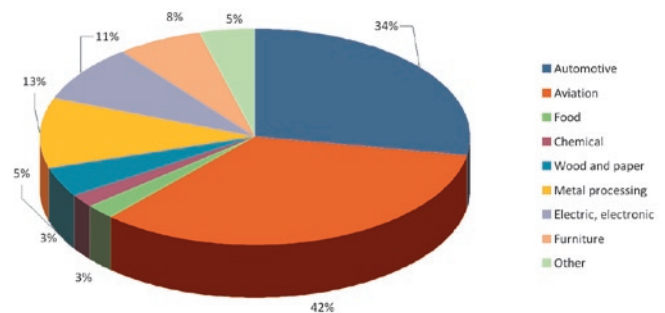


Fig. 1. Enterprises structure based on a business type

big-batch production as a dominant type of production – 27%. In the 6% of the surveyed companies, there are a few types of production combined at the same time.

Most of the surveyed companies (91%) are privately owned, the rest (9%) are state-owned (Fig. 3). 68% of them possess foreign majority capital, 15% domestic majority capital, whereas 17% possess entirely Polish capital (Fig. 4). In most of the companies mainly CNC machines are used.

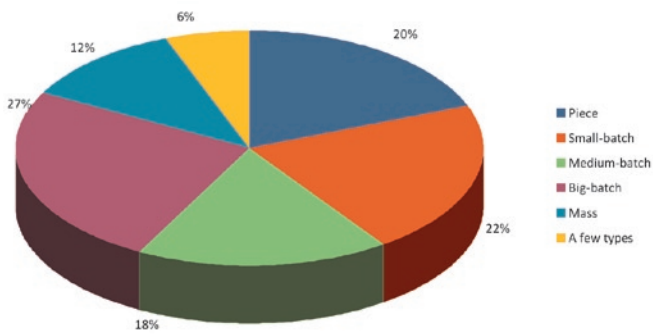


Fig. 2. Enterprises structure based on a production type

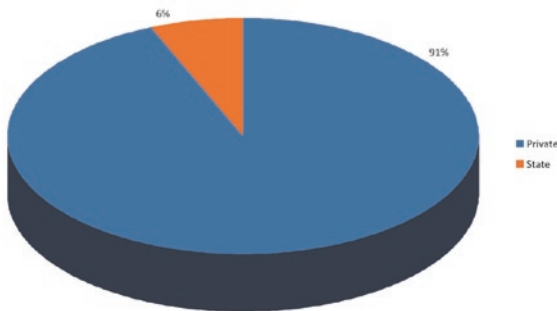


Fig. 3. Ownership type of the surveyed enterprises

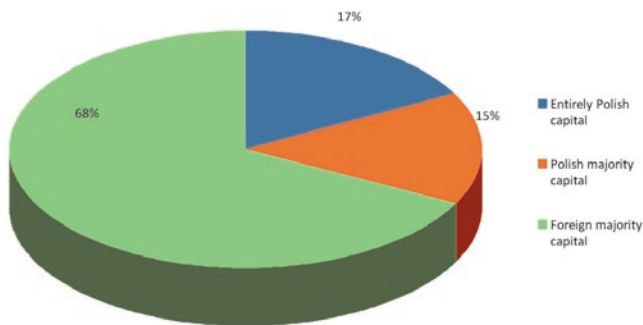


Fig. 4. Type of capital in the surveyed enterprises

In most of the surveyed enterprises, numerically controlled machines prevailed (74%). Among other technical machines, automats were mentioned.

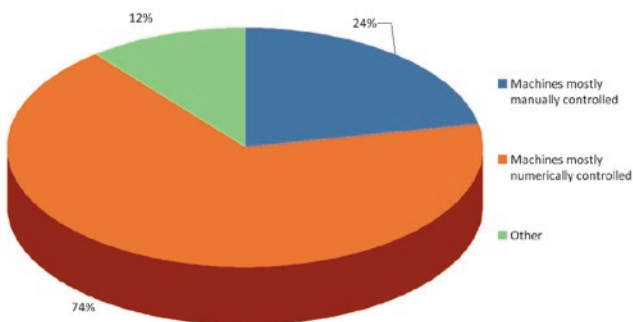


Fig. 5. Kind of machines in the surveyed enterprises

Most of the surveyed enterprises, because 72%, describe their situation as developing, and 28% of the enterprises as stable. None of the companies described their situation as difficult.

## 5. Survey results

### 5.1. Ways of technological machines supervision

The survey shows that merely one of the surveyed company uses only the strategy based on a failure removal (Fig. 6). Yet, performing planned inspections by maintenance services is the most commonly used strategy as 65% of the surveyed companies employ it. 63% of the companies implemented a technical condition assessment by an operator before taking up work. Additional data show that e.g. monthly machines cleaning and their general inspections are also performed.

In most of the companies (77%), the actions connected to machines are partly conducted by external companies; however none of the companies commissions all the technological machine park supervision tasks to an external company on the basis of outsourcing (Fig. 7).

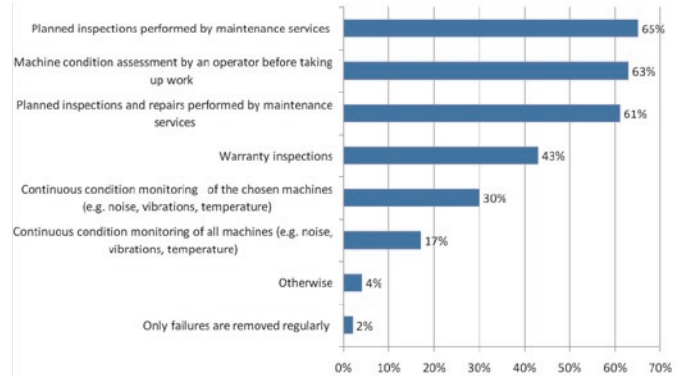


Fig. 6. Ways of the technological machines supervision

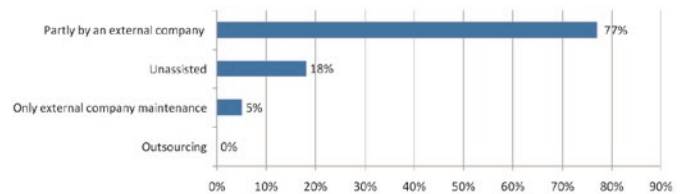


Fig. 7. Realization of the technological infrastructure maintenance tasks

18% of the companies implement the process of the machines supervision independently, and in 5% of the cases machine supervision tasks are performed within external companies maintenance.

### 5.2. Types of machine-related information recorded in enterprises

The decisions on the actions within the technological machines park supervision should be based on facts. It can be said that efficiency of the technical infrastructure management depends largely on the kind and amount of information on machines that is gathered. Since we don't know if there are any problems and where they are, we are not able to either eliminate or prevent them.

As the author points out in paper [13] collecting the necessary information, taking right decisions at the right time as well as providing intended actions and reactions are an on-going challenge for an organization's information system.

One of the groups of information which should be recorded in companies is the information on downtimes. The surveys show that the most commonly recorded kinds of downtimes are machine failures (Fig.8), what was indicated by 93% of the surveyed enterprises. In 71% of the companies, the recorded downtimes are caused by changeovers.

The kinds of information on machines gathered in companies are diverse. They regard both single workstations and production lines



or production departments. They concern machine uptimes, waiting time for service, machine spare parts, efficiency as well as machines capacity. The studies showed that the information which was most commonly gathered in companies in order to facilitate machine-related actions is the information on a number of failures of individual machines (72%). Picture 9 shows other collected information and the percentage of the enterprises that record this information.



Fig. 8. Types of downtimes recorded in enterprises

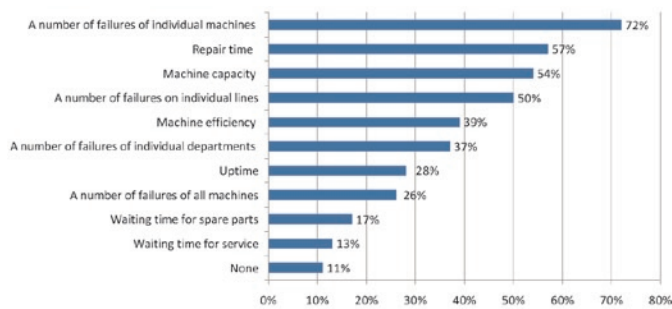


Fig. 9. Kinds of machine-related information gathered in enterprises

An important element of the completeness and credibility of the data obtained is to determine the appropriate and effective way of their collecting and recording. In most of the companies (81%) a maintenance employee is responsible for collecting information on machines (Fig. 10). It is worth pointing out that in 52% of the companies, a number of people collect and record information. A question may arise if the same pieces of information are recorded by different people and if the data overlap. However, it wasn't checked in the survey. Among other people engaged in collecting information, a continuous improvement specialist and a technologist were mentioned.

In 65% of the cases, the place of recording the information regarding machines is the maintenance department (Fig. 11). In 42% of the companies the information is directly entered into IT system e.g. information kiosk located in a production hall.

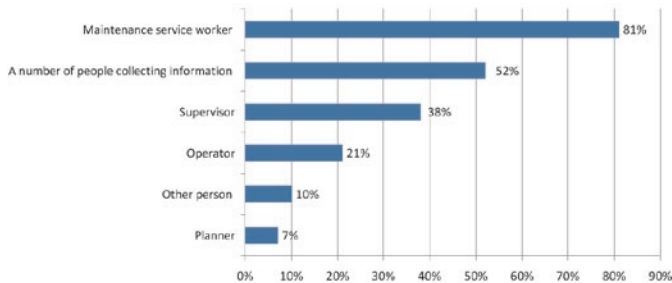


Fig. 10. People responsible for collecting information regarding machines in enterprises

Only in 16% of the companies machine-related information is recorded in the planning department.

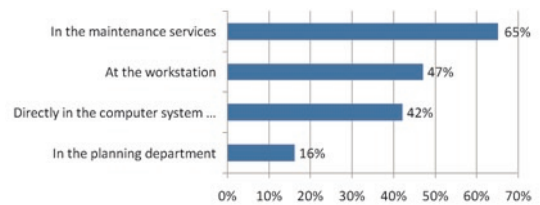


Fig. 11. The place of collecting information regarding machines in enterprises

### 5.3. Actions taken in order to minimize unplanned downtimes

It is important in minimizing downtimes to perform the appropriate tasks. These actions can be performed both by an operator directly on the machine as well as by the services established in an enterprise for this purpose.

The surveys show that in order to minimize machine unplanned downtimes the most commonly taken actions are (Fig. 12) machine modernization (69%), preventive maintenance (64%) and autonomous maintenance by an operator (64%).

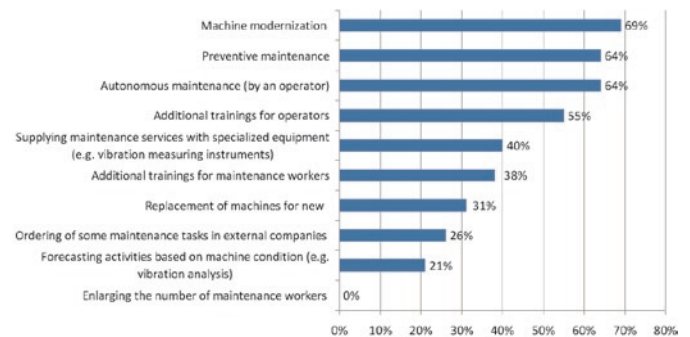


Fig. 12. Actions taken in order to minimize unplanned machine downtimes

Only 31% of the companies showed that they decide to replace machines and none of the surveyed enterprises increase employment of maintenance workers to prevent unplanned downtimes.

### 5.4. Data analysis

In the further analyses, the authors looked for similarities between:

- the type of capital and the form of actions taken (Fig. 13),
- the business type of a company and the form of actions taken (Fig. 14),
- the production volume and the form of actions taken (Fig. 15),
- the type of capital and the information on infrastructure gathered in an organization (Fig. 16),
- the business type of a company and the information on infrastructure gathered in an organization (Fig. 17),
- the production volume and the information on infrastructure gathered in an organization (Fig. 18).

For the data presented, Chi<sup>2</sup> analyses were conducted to evaluate if there is a statistically justified influence of a business type, type of the possessed capital, or a production volume on the actions regarding infrastructure supervision or on the information collected. The analyses were conducted using Minitab 16 program, and their results are presented in Table 3.

The analyses conducted show that neither the sort of actions taken within the technological machines park supervision, nor the kind of information collected is conditioned by the type of capital, or business type, or production volume in large enterprises.

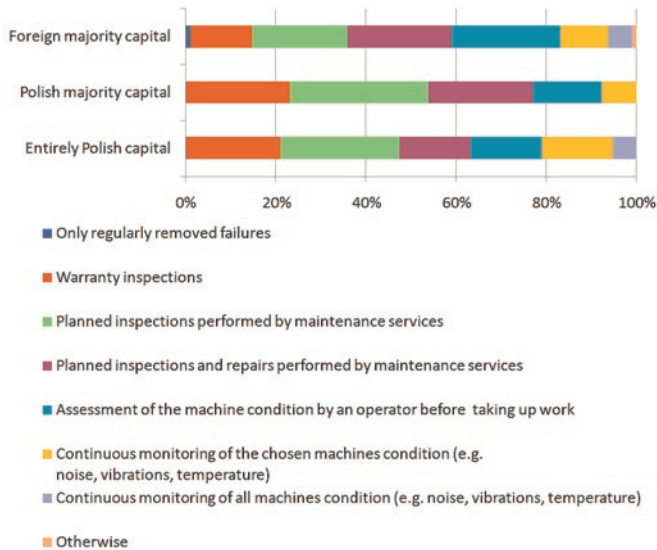


Fig. 13. Actions taken in order to minimize unplanned downtimes dependent on the type of company capital

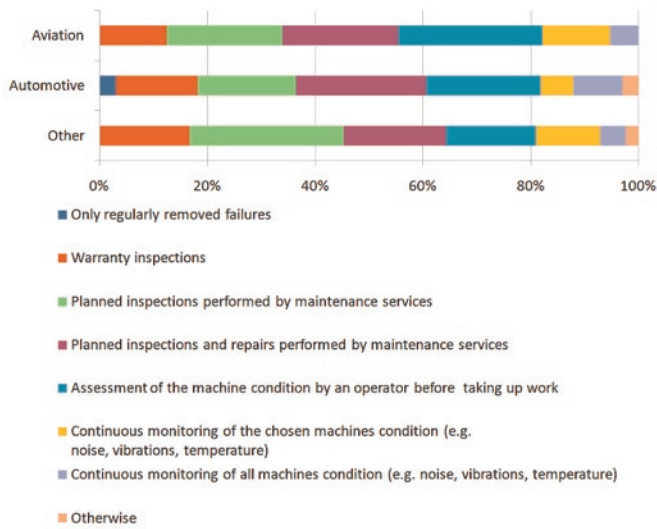


Fig. 14. Actions taken in order to minimize unplanned downtimes dependent on a business type

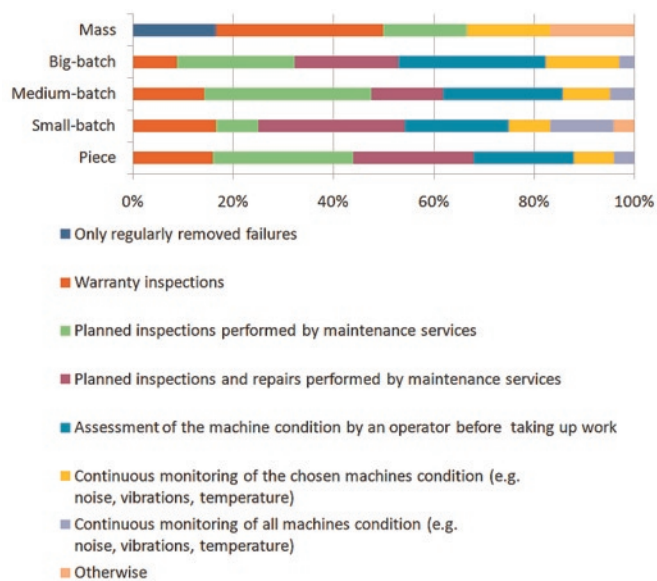


Fig. 15. Actions taken in order to minimize unplanned machine downtimes dependent on the production volume

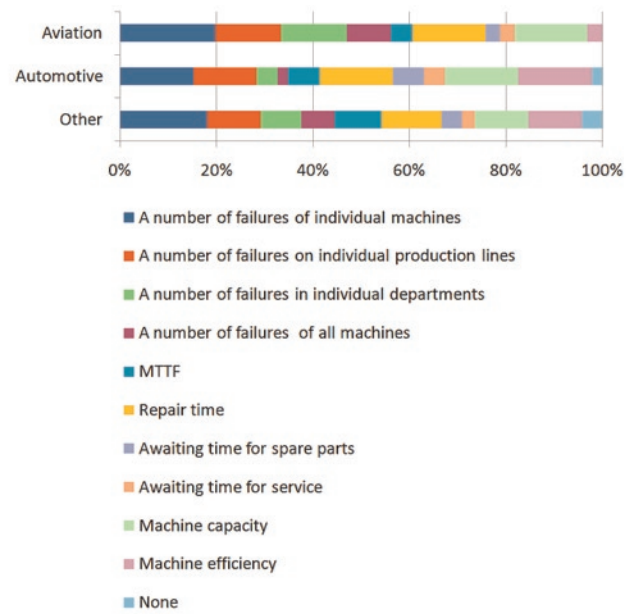


Fig. 16. Information regarding infrastructure recorded in enterprises dependent on the type of the company capital

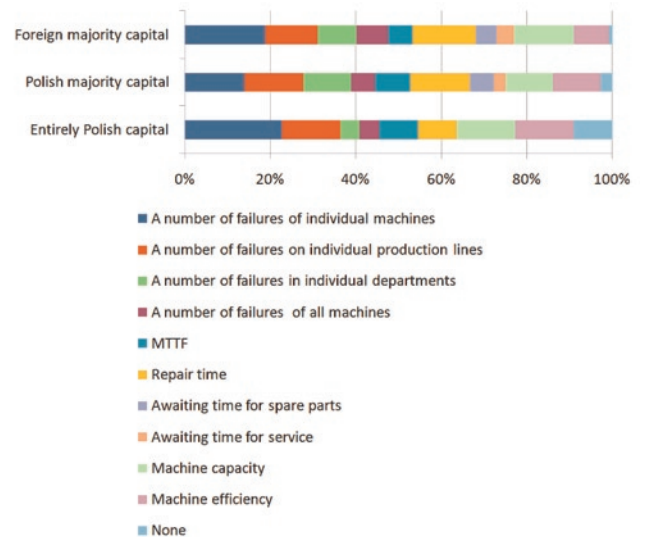


Fig. 17. Information regarding infrastructure recorded in enterprises dependent on a business type

Table 3. Hypotheses made and P-values obtained

It. No.	Hypothesis	P-value
1.	There is no difference in actions taken between the enterprises with Polish capital or Polish majority capital and the enterprises with foreign capital	0,726
2.	There is no difference in actions taken among enterprises of different business types	0,941
3.	There is no difference in actions taken among enterprises with different production volume	0,755
4.	There is no difference in the information recorded between the enterprises with Polish capital or Polish majority capital and the enterprises with foreign capital	0,811
5.	There is no difference in the information recorded among enterprises of different business types	0,798
6.	There is no difference in the information recorded among enterprises with different production volume	0,940

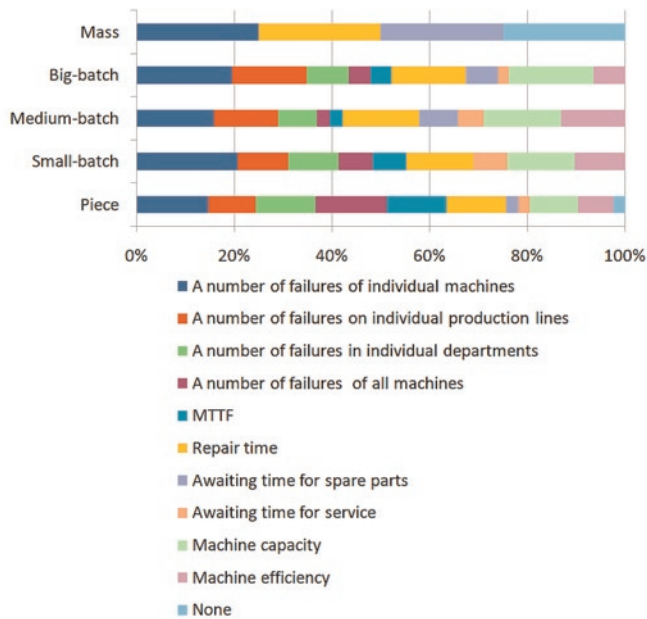


Fig. 18. Information regarding infrastructure recorded in enterprises dependent on a production volume

**5.5. Evaluation of the actions performed within technological machines park supervision in comparison to the theoretical assumptions**

The main aim of the study was the identification of the real actions that are performed in large enterprises within the technical infrastructure supervision. Table 4 shows the actions related to the machine supervision recommended by the theory within defined strategies and these which were identified as used in practice. It also presents the percentage of the enterprises which perform specified tasks.

Based on the analyses of the data from table 4, it may be concluded that the most commonly used approach in enterprises is preventive maintenance (PM): warranty inspections, planned inspections performed by maintenance services, planned inspections and repairs performed by maintenance services. Occasionally, the activities recommended in condition based maintenance (CBM) are realized. Fortunately, the less frequently used approach is the corrective maintenance approach (CM), which is directed only to the actions related to removing already arisen failures and undertaking inspections required in the warranty period. A mixed approach is also frequently used, and only 26% of the surveyed claimed the use of outsourcing (O).

**6. Summary and conclusions**

The proper performance of the technical infrastructure management in an enterprise requires regular, planned and economically justified actions. The surveys conducted show that managers of large enterprises, being aware of the technical infrastructure influence on the final quality of products and on the enterprise competitiveness, take up various actions in order to improve the efficiency of machines and appliances operation.

In a number of companies, regular inspections are conducted as well as different actions are undertaken in order to eliminate unplanned downtimes and failures. The survey results show that preventive maintenance (PM) is the most preferably used approach. However, companies are more willing to use the continuous monitoring as well. 30% of the surveyed indicated that they use continuous monitoring in reference to the chosen machines.

However, there is still the need of performing the tasks connected with both the development of the technical infrastructure supervision strategy as well as promoting the knowledge of the current and applied strategies.

Table 4. The actions related to the machine supervision recommended by the theory in realization of the technical infrastructure supervision strategies defined and used in practice together with the assessment of their practical use

Supervision strategy					Actions related to machine supervision recommended by the theory within the defined supervision strategies	Recommended by theory	Used in practice	Percentage of the companies where the actions are applied in practice [%]
PM	CBM	CM	MS	O				
					Machine modernization	+	+	69
					Planned inspections by the maintenance services	+	+	65
					Technical condition analysis by an operator	+	+	64
					Preventive maintenance	+	+	64
					Assessment of the machine condition by an operator before taking up work	+	+	63
					Planned inspections and repairs realized by maintenance services	+	+	61
					Additional trainings for operators	+	+	55
					Warranty inspections	+	+	43
					Supplying maintenance services with specialized equipment (e.g. vibration, noise measuring instruments)	+	+	40
					Additional trainings for maintenance services workers	+	+	38
					Replacement of machines	+	+	31
					Continuous monitoring of the chosen machines condition (e.g. noise, vibrations, temperature)	+	+	30
					Ordering some maintenance tasks to external companies	+	+	26
					Forecasting activities based on the machine condition (e.g. vibration analysis)	+	+	21
					Continuous condition monitoring of all machines (e.g. noise, vibrations, temperature)	+	+	17
					Only failure removal	-	+	2



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