A NEW CONCEPT OF EVALUATION OF THE PRODUCTION ASSETS

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***Abstract*:** Production assets management in a company is a traditional function, which in the period of transition of the Polish economy gradually lost the role of co-relation with the production function to the function of marketing and sales, finance or even logistics. An efficiency was selected as the main operating criterion at the company level i.e. the ability to reach a set goal of the final activities. Technological efficiency at the level of the production station is expressed by the ratio of technological efficiency, at the level of production cell the efficiency of technology influence on efficiency of production cell. The inspiration for this paper were the new approach to company value on the market, including the value of assets, and advancement in the production technology and an appearance of modern tools.

Keywords: production assets and technological efficiency in the enterprise, flexible and innovative production, quality and price efficiency, market demands, value and company management.

1 Introduction

Business processes in companies are strictly related to the asset management. In the period of structural changes the following factors affect the effectiveness of production assets: asset restructuring, privatization, implementation of quality assurance systems, new markets and new technology, also internationalization and globalization in the multinational business. Competitors on the markets of all industries focused their activities and aimed at utilizing economies of scale of production and the new role of marketing. Maintaining the conventional production equipment it is impossible to meet new requirements and compete on the market in the future. The preferred variant of technology selected on the basis work consumption minimization criterion led to a large fall in employment, however, the development investment guarantees significant growth in efficiency of companies. The market is characterized by high influence of innovation in products on technology modernization.

Gradual implementation of new technologies and modern production processes into businesses requires increased efficiency of production assets. Innovation in technology became the main driving force behind the decrease in costs, increased productivity and increased quality. The fixed assets analysis traditionally comprises a set of partial ratios such as: fixed assets possession ratio, modernity of fixed assets ratio, and fixed assets utilization ratio. The productivity ratio is a synthetic measurement tool. The matters of technical system exploitation efficiency is further developed in the science of exploitation. A new idea of efficiency results from a research assumption that development of production systems, including technology and production, shaped by the market needs, is the basis for production assets efficiency.

2 The genesis of the problem of assets and efficiency in the enterprise

2.1 Market impact on the development of production in the enterprise

Production assets management in a company is a traditional function, which in the period of transition of the Polish economy gradually lost the role of co-relation with the production function to the function of marketing and sales, finance, or even logistics. A new approach to company value on the market, including the value of assets, and advancement in the production technology and appearance of modern tools are an inspiration for search of such production fixed assets which would constitute a material source of competition in the scope of quality, efficiency and utilization and costs.

The management cadre tend to forget that in modern companies the highest element of costs is not an employee, but the depreciation of a machine. Advancements in technology are so fast nowadays that it is difficult to assume a 20 year machine exploitation time (recommended time – 5 years).

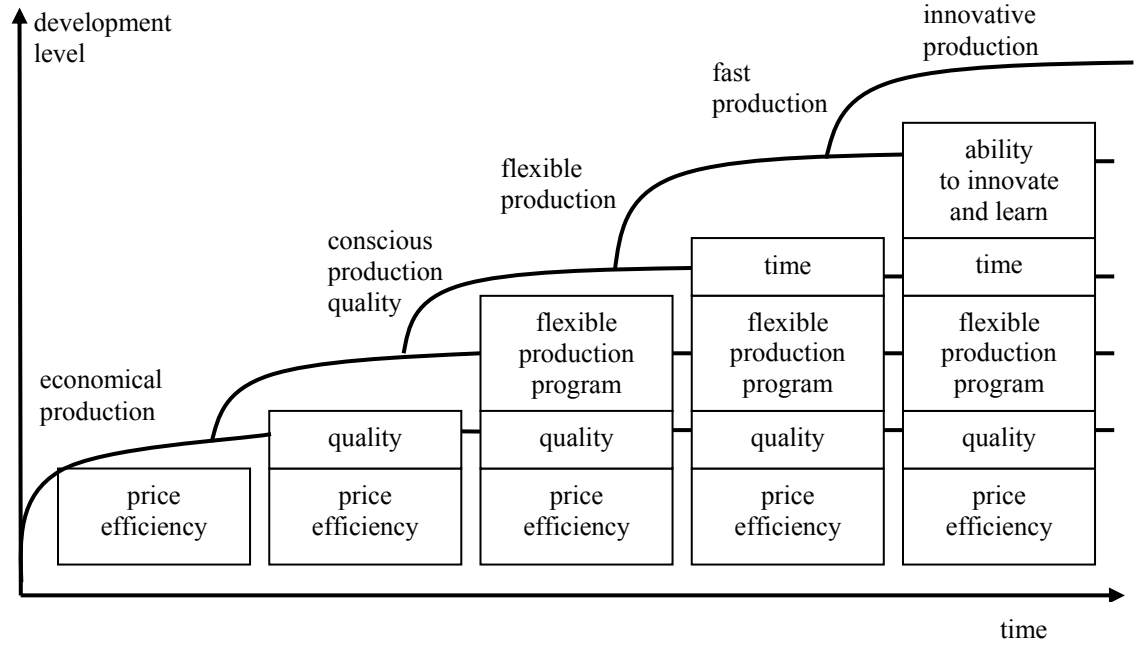

Figure 1. Evolution of production as a consequence of changing market demands (*source: G. Spur [52]*)

A higher efficiency of machines results enforced higher efficiency of an employee.

Apart from quality, productivity and cost reduction producers should present flexibility of operations i.e. an ability to provide a fast and efficient reaction to the needs of the market and client's preferences. One of the main goals of a company is to define a product and ensure its place on the market. Execution of the goal requires new product planning, flexible manufacturing and introduction of the products on the market.

The fundament of balanced growth strategy of companies is efficient basic functioning of the production system. The business is shaped by market needs supported by the rules of the market economy on one hand (from outside to inside) and from the other side (from inside to outside) by production potential limited by technology and means of work. In order to increase client satisfaction and efficiency of production the space between the demand and the supply and the client and the producer is filled with advancement in manufacturing technology and processes of integration of human and technical resources. J. Honczarenko [15, p. 27] explains that the manufacturing process is subject to change starting from mass production to the philosophy of flexible, cost-effective, lean to agile manufacturing.

The evolution of production (Fig. 1) develops from economical production to innovation in the production. The essence of Fig. 1 is the presented need for purchase of new skills by organizations, in order to meet increasing and more complex market needs.

Production is a function in a company, therefore like any other function it is a means to goal of an organization as a whole. Goals require engaging the management cadre – including the production department cadre. The goals of a company are generally of economic, material, system nature and are the main criteria of selection of type and direction of activities. For example: execution of a sales plan, increase in profits, development of new products, implementation of a new technology.

Strategic decisions taken within the production function are developed into tactical and operating decisions (what technologies are appropriate for the assumed scale of production, reliability of equipment, ensuring quality, logistics, and production financing).

One of operating decisions is a plan of readiness and reliability maintenance of the production assets. Execution of plans often requires investment – purchase of new means of work, liquidation of worn ones. A company's ability to compete on a free market requires an intensification of the production business through utilization of all sources of increasing efficiency of its work. A substantial source is effective production assets management.

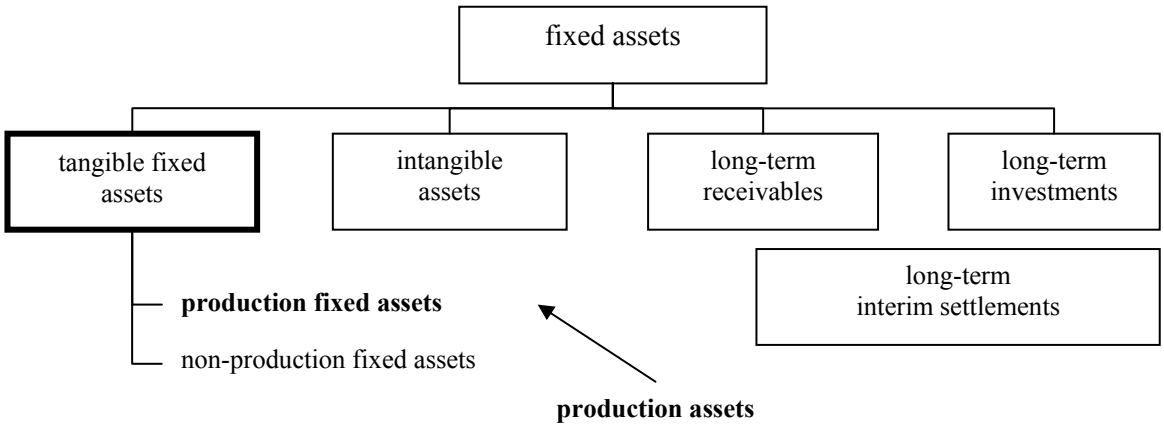

Figure 2. Division of fixed assets with indication of production assets
(*source: author's own work on the basis of the accounting law [54]*)

Introduction of new technologies and methods of production results in dilution of quantitative criteria of production scale division, sizes of production batches and the number of various products in the production system. Also production assets efficiency limited to an economic criterion is often in the statistical dimension in the production business. Traditional production systems with excessive production capabilities, show a tendency to decrease the machine utilization time ratio. Experience from exploitation of advanced production systems shows that as a result of dynamic allocation of tasks the load on particular machines increases, however, it is not a factor that decides about the economic efficiency of the system. The decisive factor becomes the disposable time of the system, not exploitation costs.

Innovative production cannot be based on advanced technology alone, but also requires a production structure creation, which will be able to adopt to changing conditions and manufacture a wide range of products using the same available means.

2.2 Definitions, functions and efficiency of production assets

Production assets are key asset resources, which are divided [54, p. 67] into: intangible assets, material fixed assets, long-term receivables, long-term investment and long-term interim settlements (see Fig. 2).

Fixed assets [54, art. 3, section 1, point 12-13] are defined as assets not classified into trading ones, being „controlled by the entity resources of credible value, being a result of past occurrences, which will result in future inflow of economic benefit into the company". Controlling of assets means that the given entity is able to receive future economic benefit resulting from the use of available items of assets.

Fixed assets are working mean aimed at production goals [4, p. 12] in a longer period of time, maintaining their natural physical form, not being a part of products manufactured by their use. Fixed assets are work means of set value and time of use.

In the science of machine and technical means exploitation there are following definitions: single technical object, a group of technical objects, exploitation object, exploitation system, technical system, exploitation of technical systems.

In the engineering of production ([10], [11], and [15]) a system, a technical system, manufacturing, production, manufacturing system, production system, technical means of production. I. Durlik [11, p. 33-34] divides technical production means, as one of basic elements of the input vectors into production system:

- the premises of manufacturing plant and the production area,
- technological equipment,
- buildings,
- piping, electrical installation, IT network.

Characteristics of fixed assets according to varying criteria of division defines and sets the structure of means collection, their destination and way of use.

On the basis of the function (destination) criterion performed by fixed assets numerous researchers ([4],

[16]), and the industrial practice defines two basic groups:

- production fixed assets,
- non-production fixed assets.

The difference between the production and non-production fixed assets is such that in the production process the value production fixed assets is transferred in amortization on manufactured products.

The criterion of production necessity and relevance are characteristics of working means [16, p. 23], and without participation of means of this type, it is impossible to deliver the production process relevant to the given company.

Production assets

Production assets are a part of fixed assets not classified as non-production fixed assets, meeting the criterion of production necessity and relevance and used for realization goals of the company and the functioning of production systems.

In the multidirectional effect of fixed assets on the quality of the production process there are following functions to be distinguished: technical, technological, economic, social, and asset ones.

Technical function

Technical function is delivered through relations of material objects, structures describing the location of elements in relation to one another, and reason-effect mechanisms resulting in processing energy and information. A change in the level of physical values is described as the physical and chemical state, which the basis for a formal description of technical state of facilities.

Reliability and durability are considered main criteria of assessment of useful value of the currently produced manufacturing equipment. The period of exploitation may be considered a measure of durability. An efficiency of facilities comprising the fixed assets, decreases over time of exploitation. Reliability is defined as a quality of a facility set as its capability (the level of trust) for proper functioning within a set time and set circumstances.

The development of technical function not only in the product or engineering innovation, but also the market one, positively affects the increase in production machinery and equipment efficiency.

Technological function

Technological function – shapes the manufacturing processes and the type of applied technology, affects the continuity and type of processes over time. Technological facilities fulfill not only basic functions, but also auxiliary ones.

Technological function is normally interpreted as a function related to the manufacturing process. The function is directly related to the accuracy and efficiency of a process and technological complexity of the structure. A decrease in the work consumption is possible in a technological process. Automation is a concept of technological system [9, p. 34]. New technologies and flexible manufacturing processes ensure substantial improvement in reliability and stability of production process. An evaluation of the technological position of a company enables determination of a „technology gap" – which limits development of a company. Currently technology is a new factor of company competitiveness.

Economic function

Purchase of items of fixed assets requires investment expenditure and then expenses in the form of labor costs, and facility maintenance in the manufacturing process. Depreciation of fixed assets is an economic category, that may serve the purpose restoration of facilities, in order to counter the process of their further wear. Depreciation serves a function of transferring the worn fixed assets value onto the production costs. The criteria of technology attractiveness and competitiveness, as well as fixed assets, are considered economic criteria. The economic function – often as an obligatory requirement, affects undertaking activities aimed at improvement of production capabilities utilization. Production costs depend on the size and variety of manufacturing. The choice of reconstruction form is affected not only by technical factors, but also the economical ones.

Development of new technologies increase capital requirement. A company functions in a set economic system, and the economic function is an integrator of its internal and external functions.

Social function

Manufacturing business creates work places. Capital consumption of workstations affects the amount and type of work. Development of key technology eases human effort at work and increases employment of skilled staff with new qualifications.

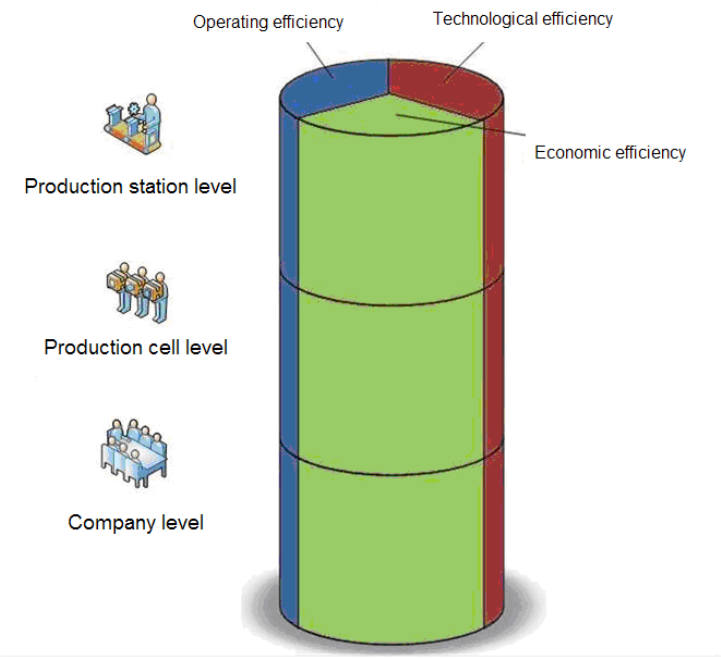

Figure 3. Areas of assessment of production assets efficiency
(*source: author's own work)*

Technological advancement deepens the process of societies qualifications all over the world. Together with the development increases productivity measured as value of sales pre one employee.

Employees require of a company that their work makes sense and was something serious [9, p. 289], and the way of their work organization indicated an employer's interest in good work. A new accent of a social function is the social and cultural aspect of human resources in the organization of work.

Moreover, the social function covers the tasks of improved working conditions and should indicate information about negative results of work in a given place of work.

Restructuring activities [17, p. 110] in the Polish economy affected: changes in the employment structure, improved discipline of work, promotion of employees' creativity, limitation of the social function.

Asset function

Asset function – in the process of company value management there emerges a role for the assets function and its influence on productivity. A subject of analysis may be a company as a whole, or its separated part, or items of assets. An instrument of asset function are methods of valuation of assets and company revenue [40, p. 26-32],

Key elements of the valuation, that affect the assessment of the company, are:

- market value of shares,
- net assets value,
- growth in profit per share ratio,
- operating and financial risk.

A new role of assets in the economy affected the shaping of a new ownership structure.

The asset function is information about the real economic value of a given entity and argumentation upon decisions regarding purchase or sale of items of fixed assets. The listed functions of production assets in business activities indicated areas in which possibility of increased efficiency of the assets may be found.

Production assets efficiency

The notion of production assets efficiency is not unambiguous, which results from the very nature of efficiency, the method of its expressing and measuring (see Fig. 3).

M. Bielski [2, p. 104] explains that companies, in the decision-making process, are guided by adopted goals and possibly low expenditure on their achievement, should asses efficiency as the level of achievement of set goals, and then the level of utilization of possessed resources.

It may be stressed that the unambiguous notion of efficiency does not limit us to only determining general company efficiency – as a synthetic measurement, but also leaves room for the choice of selection of rati-

os and efficiency measures in implementation of ventures relating to particular functions or resources (including production assets).

Therefore, numerous particular efficiency notions, such as: economic efficiency – the result of business activities calculated as reached result to the input, organizational efficiency, adaptive efficiency], and innovative efficiency.

Operating efficiency [49, p. 63] related onto fixed assets is a quality determining their ability of being the efficiency mode, enabling delivery of set production tasks. The qualities of fixed assets, in such a form of defining operating efficiency, are: reliability, readiness, and lifetime.
There are substantial efficiency increase possibilities on the border between technology and production, the use and maintenance of machinery, and product design and technology.

Fixed assets efficiency is a multidimensional notion, therefore, the economic, technical, organizational and management literature comprises term such as: efficiency, efficacy, usefulness, reliability, productivity, economy. A synthetic fixed assets efficiency measure [16, p. 193], sets an economic variable, expressing a relation of a given goal function level of a company F to expenditure (resources) of fixed assets N, necessary for execution of the function:

$$E_m = \frac{F}{N} \quad (1)$$

Such formulated fixed assets efficiency measure is a mirror of production means efficiency measure expressed by the goal realization level and the size of effort borne in relation to the effort or resources of the factors.

Another form of the above presented E_m formula is as follows [16, p. 193]:

$$E_m = \frac{Z}{K_m} \quad (2)$$

where:
Z – the level of financial result (profit) of the company,
K_m – costs of exploitation of fixed assets.

The presented relation between the exploitation costs may lead to a stimulation of fixed assets efficiency increase in a company.

R. Borowiecki [4, p. 93] suggest two phase study of fixed assets management efficiency. The first phase assumes assessment of fixed assets productivity in relation to work efficiency and its technical equipment as a starting point for assessment of the company management in the scope of fixed assets utilization.

The second phase – there are detailed studies covering the following: ratios and coefficients of the size of fixed assets; the ratios of technical advancement in the area of fixed assets; ratios and coefficients of utilization of machines and equipment space.

2.3 The goals and scope of production assets efficiency

The main goal, which is increased assets efficiency, was set a company level – a business entity running production or service business on its own, in order to gain benefits. A production entity, as an open system comprises numerous sub-systems: development, manufacturing, supply, maintenance, information, and management. Material production factors of a system comprise material grounds for growth in utilization of production capabilities of an entity.

Partial goals are reached in a given period of time and space using certain resources. A program of assets efficiency improvement may comprise numerous partial goals such as: optimal deployment of workstations, improvement in raw material flow in the manufacturing process, shortening in technological times as a result of introduction of a new technology, increase in productivity of manufacturing workstations.

Goals related to usage of production assets may stress the varying needs of processes and their importance in a company. For example: the main goal of production assets, in respect to the process continuity criterion, is to maintain efficient manufacturing guaranteeing productivity, quality and safety.

An energy efficiency improvement program in a company comprises goals of decreased energy costs of production halls and energy-saving equipment. An increase in production assets efficiency may be executed through:

- new and modern technological solutions,
- increased efficiency of workstations,
- utilization of production capability,
- efficient acquisition of orders,
- staff training on the exploitation of manufacturing equipment.

Production assets efficiency may be discussed from various point of view, therefore there might be varying assessment criteria, such as:

- economy, setting a relation between the value of gained effects and a the level of efforts borne in a given period of time during the use of the assets,
- efficiency, an ability to reach states with positive evaluation from the achievement of external goal point of view.
- efficacy, a quality of assets enabling a possibility of remaining in the state of ability of full execution of production goals,
- readiness, a quality of assets expressing a capabilities necessary in a given period of time for delivery of the use process in line with technological requirements,
- effectiveness, setting out the intensity of execution of production tasks,
- capital consumption of manufacturing workstations, which increases with technology development.

The scope of production assets efficiency is limited by two elements: the first one – the level of efficiency, the second one – the criteria of efficiency. In a reference standard there are three levels of increased efficiency:

1) the enterprise level (a production system),
2) the production cell level,
3) the manufacturing workstation level,

and three criteria of assessment (evaluation) of efficiency:

1) economic criterion,
2) technological criterion,
3) operating criterion.

As a result of such division there are nine areas of increase and assessment of production assets efficiency in a company. Each level is subject to evaluation of the following types of efficiency: economic, technological, and operating one.

3 Conditions for change and their impact on the management of productive assets

3.1 Analysis and assessment of fixed assets efficiency

The business of each company, including its fixed assets and processes, requires periodical analysis and assessment. An analysis should allow, on one hand, determination whether the to date destination and utilization of production assets brings expected results (an ex post analysis), and, on the other hand, enable determination of directions and methods of increasing efficiency in the manufacturing process (an ex ante analysis). An analysis applying to the company assets management is generally know as assets analysis.

An ex post analysis of fixed assets efficiency was a subject of intense studies and literature until the 1990s. Economic changes introducing free market require a new approach to searching for direction and methods of increasing production assets efficiency.

From the subject point of view the following analysis and evaluation techniques are worth mentioning:

- productivity – a synthetic measure of fixed assets efficiency,
- utilization of fixed assets,
- influence of fixed assets on production and financial results.

A universal formula – fixed assets management is based on the rational management principle. The core of the principle is ensuring such management so that with „a given level of effort receive highest possible level of goal achievement, or upon a give goal achievement level utilize the lowest possible level of effort" [1, p. 13]. The first part O. Lange [14, pp. 217-218] is known as the highest effect principle, or highest efficiency principle, the second one – the lowest effort principle, or the cost-efficiency principle.

A consequence of the principle is a scope of fixed assets efficiency in question, covering activities aimed at intensification of fixed assets management strategy (restructuring, utilization, restoration, modernization, development) ([43, p. 11], [20] and [57]).

„Fixed assets management is the whole of planned, organizationally ordered and continual activities aimed at securing its resources, their readiness for production, and appropriate application in the manufacturing process, and reproduction that is adequate to the development tasks of the company, in line with its production needs" [43, p. 13].

The relation between the scope pursuit goal and the sum of efforts is a measure of management efficiency. In an analysis of fixed assets, the following general ratios are derived from two basic economic values of a company: production (P), employment (Z), fixed assets (M):

- fixed assets productivity ratio (P : M),
- technical equipment of work ratio (M : Z),

- efficiency ratio (P : Z),
- production work consumption ratio (M : P)

$$\frac{P}{M} = \frac{P}{Z} : \frac{M}{Z} \quad (3)$$

R. Borowiecki [4, pp. 52-56] presents cases of co-relation from the formula (3) and influence of production, employment, and fixed assets on changes in productivity.

The following set of partial ratios is also used in fixed assets analysis:

a) ratios of fixed assets ownership (value, structure, wear level, depreciation);
b) ratios of fixed assets modernity (e.g. numerical control, automated measurements, etc.);
c) ratios of fixed assets utilization (time, efficiency, area occupied, modernity).

Changes in partial ratios, due to the requirements of statistical analysis, and economic studies in the aspect of planned business, had varying accents in their content and evaluation. A result of the change is a decrease in the level of interest of the middle management level in the practice of decision taking, in particular regarding production. Numerous of those ratios were transferred to the production continuity functions.

After 1990 a new meaning emerged for the financial analysis, comprising vertical analysis of assets, including fixed assets and current assets.

An assessment of fixed assets efficiency may be made on the basis a comparative analysis based on specimen set of inequalities of ratios [2, p. 40].

A specimen set of inequalities of basic quantity ratios is as follows:

$$I_R < I_M < I_P < I_Z \quad (4)$$

where:

I – dynamics index,
R – employment level,
M – state of items of assets,
P – sales revenues,
Z – profit of the company.

Technological progress of fixed assets should have higher dynamics in relation to employment. The process contributes to an increase in efficiency, resulting in higher production dynamics. The profit dynamics grow faster than the production dynamics. A specimen set of inequalities is difficult to establish in the conditions of variable external environment of companies.

In methods of analysis of economic efficiency of fixed assets in a company the following methods are presented [16, pp. 204-220]:

- econometrical methods of fixed assets efficiency assessment,
- benchmarking analysis of fixed assets efficiency analysis.

The topic of technical systems exploitation efficiency is developed in studies of exploitation science development [74, pp. 95-121]. Z. Cygan stresses the cognitive meaning of technical and economical ratios of exploitation [5].

The purpose of analysis and assessment of production assets efficiency is achievement of effective management of assets and assessment of the influence of assets on economic and financial results of an enterprise.

3.2 Production assets as elements of value of a company

A condition for efficient company management is the motion of value creation not only in the long-term cash flow, but also in the profit per share area. The growth in value depends on goals set at the strategic level, regarding the area of business. From this point of view investment decisions become important. Fixed assets are of investment nature. In the value management process there is a problem of assets valuation and their influence on productivity.

The size of assets may be discusses only when there exist conditions of their useful value. The value of assets determines the value of financial assets which would have to be allocated at restoration of assets in a given time, necessary for further functioning of the company. The following are qualities of value of assets [22, p. 47]:

- the value of assets is a current value as at the time of assessment,
- the value of assets is a value of continuation of business running and not the value of its liquidation,
- the value of assets is a total of amounts set for the restoration of particular items of assets.

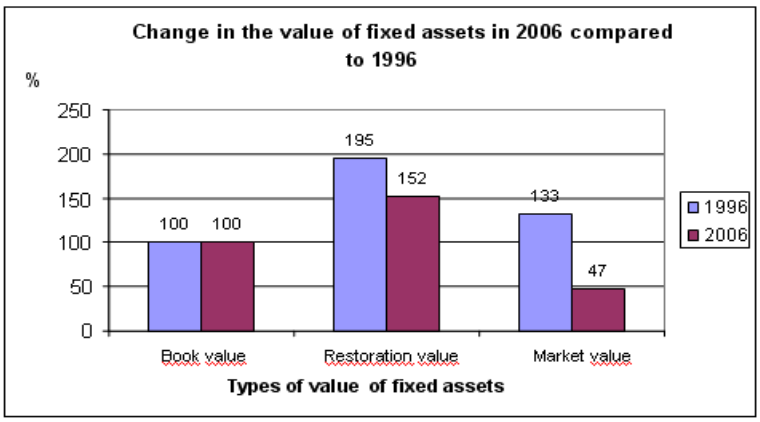

Figure 4. Changes in the value of fixed assets
(*source: author's own work*)

A relation between the assets and revenue value of a company has various forms of relation expresses in the formulas [22, pp. 63, 65 and 67]:

$$W = W^M + a\left(\frac{Z}{r} - W^M\right) \quad (5)$$

or

$$W = \frac{1}{2}(W^M + W^D) \quad (6)$$

$$W = \frac{1}{3}(W^M + 2W^D)$$

where:
W – company value;
W^M – assets value,
Z – standardized annual profit,
r – capitalization rate,
a – weigh factor,
W^D – revenue value.

The following assets methods serve the purpose of assets valuation:

- balance sheet method of net assets valuation, or adjusted net assets method.
- restoration method,
- liquidation method.

Fig. 4 presents a change in the value of fixed assets.

Calculation of a company value using the method of adjusted book value of net assets is performed according to a general formula [36, p. 228],:

$$W_P = (A + K_A) - (P_O + K_{P_O}) \quad (7)$$

where:

W_P – company value,
A – balance sheet value of assets,
K_A – adjustment of balance sheet value of assets,
P_0 – external liabilities,
K_{P_O} – adjustment of balance sheet value of external liabilities.

The company value using the restoration method is calculated using the following formula:

$$W_P = (A + \Delta N) * (1 - Z_F) \quad (8)$$

where:
W_P – company value,
Δ N – difference in expenditure borne on new material potential,
Z_F – physical wear of items of material assets.

The value of production assets totally or partially (together with the revenue value) directly affects the company value. In assessment of company value in the revenue method a discounted cash flow method is used. According to experts it is the basic method used in analyses of trade in companies. Increased production assets efficiency increases the revenue value of a company.

3.3 Studies over fixed assets efficiency management in the company management

There are three periods in the evolution of fixed assets efficiency management in Polish companies:

a) Fixed assets management efficiency (years 1970 – 1989)

A monographic elaboration on the topic is a publication of R. Borowiecki [4], where the following issues were presented: the role of fixed assets in the manufacturing business of an enterprise, a relation between fixed assets productivity and basic economic relations, the rules of selection and application of measures for assessment of fixed assets management efficiency. The author

explains and applies productivity as a synthetic measure of fixed assets management efficiency in a company.

In a publication of W. Janasz, E. Urbańczyk and T. Waśniewski [16], were presented three areas of studies in fixed assets management: wear and tear and economic calculus of fixed assets restoration, the influence of the economic and financial system on the restoration of fixed assets, methods of analysis of economic efficiency of fixed assets and an analysis of efficiency of utilization of fixed assets and its influence on production and financial results.

A work edited by J. Rokita [39], is dedicated to methods of fixed assets management assessment in a company. The scope of the method is of universal nature.

The movement toward productivity in the world is an impulse for research and a new look at the idea of productivity, ratios of productivity, factors affecting an increase in productivity, and productivity improvement programs ([37], [41]). It is a complex approach to productivity assessment in a company.

A development of the science of exploitation contains the issue of efficiency of technical systems exploitation, including works of Z. Cygan [5, pp.119-134], J. Lewandowski [24]. Exploitation is an interdisciplinary science consisting of tribology, elements of reliability and restoration theory, the study of reliability, technical diagnostics and efficiency of exploitation of technical systems. The studies on exploitation indicated that unjustified intensity of utilization of fixed assets without rational maintenance services – in the 1970s led to deterioration of production assets. The useful potential is a measure of a machine capability for use, however the servicing potential is a measure of machine's needs for service.

b) Restructuring of fixed assets (years 1990 – 2000)

Main problems of efficiency of company management in the years 1990 – 2000 were focused on restructuring. Restructuring of fixed assets is considered an area of qualitative changes (a change in technology and work organizations) and is aimed at increased efficiency of production capital of an enterprise. P. Glikman [12, pp. 33-44] stresses that an increase in efficiency, studied in variants: non-investment and investment, requires rejuvenation of fixed assets and am estimation of changes in employment in an economy. Z. Czyżewska [6, pp. 55-72], stresses that the structural aspects of labor resources and fixed assets management are a trial of capabilities of deciding a problem of reproduction scale of assets and the type of investment, and a speed of changes in introducing new manufacturing techniques.

Restructuring the scope of business of companies, means returning to the core competence, i.e. an area of specialization of the company [48, p. 45]. The first task in the restructuring process was getting rid of unused, obsolete fixed assets. Changes in technology were a stimulus for action in the scope of machines and manufacturing equipment replacement. An effect of these activities is a new configuration of business areas with long-term business strategy.

Ownership transformation and privatization required credible methods of valuation. Restructuring of fixed assets contributed to an increase in production assets efficiency.

c) Fixed assets management (from 2000 to now)

A rebuilding of Polish companies and adjustment to the changing environment and growing quality, efficiency, and timing requirements, requires an improvement in the material assets management, and in particular production fixed assets. The management of fixed assets comprises an integral part of company management.

New technologies are new means of work and their application brings desired technical and economical, but also social results. Attractiveness of technology contributes to a decrease in production costs and an increase in quality. It is a factor of increased sales of product on internal and external markets, and at the same time affect better utilization of production assets. New technologies are the starting point for effective creation of a manufacturing system without constant human intervention.

Radical and evolutionary changes in years 1990-1999 led to Polish companies introducing into practice new concepts of management sourced in the Lean Management process [3]. The pursuit of increased efficiency and shorter times of processes requires a complex Total Productive Manufacturing, a complex Total Productive Maintenance ([27], [8], [25] and [51]), Facility Management [53].

A new measure of production assets efficiency is OEE (Overall Equipment Effectiveness). Availability of complex workstations and production cells affects better utilization of production process capability.

4 New concept of evaluation of assets the production business of enterprise

4.1 The goals of assets efficiency study in the production business

Development of production systems results from market requirements, but also from manufacturing technologies, methods and techniques of production management available for application in a company.

Technology is often listed as a factor of international competition of companies. A common element for companies achieving large and small successes is a fact that they achieve efficiency (widely defined) through implementation of innovation. Innovation should be perceived more as cumulated improvements and ideas rather than a significant technological breakthrough [46, p. 154]. Innovation mechanism known to one part of a company may be used in another part, which requires improvement (reformation). For example; management – production – maintenance of machine running.

New concept of efficiency results from adoption of a research assumption that development of production systems, including technology and production, shaped by market needs, is a condition of production assets efficiency.

One of the factors of production development is durability and restoration of work means. Restoration of means of work means adjustment of potential production capabilities to changing environment. An average period of technical facilities exploitation is much shorter than their potential physical lifetime. First symptoms of loss in assets efficiency may be as follows: high costs, a fall in sales activities, a wide scope of business, obsolete technologies and fixed assets, low efficiency of organization at the level of company. Activities undertaken to improve efficiency are: a change in the investment policy, disposal of unused assets, search of new sales market, new definition of core business, acquisition of new technologies and machines.

The main goal of a new study concept is to increase production assets efficiency in a company. Partial goals – enrichment and improvement of assets:

- selection and accessibility of means for achievement of goals,
- efficiency in realization of production tasks,
- an increase in efficiency of workstations,
- an increase in fixed assets productivity,
- a decrease in own costs of production.

Increased assets efficiency is characterized by a system analysis qualities, and its frequency and scope is determined by projects, ventures, activities contained within company management programs. A system analysis of a problem contains following stages:

- examination of considered goals, or multidirectional ventures,
- an analysis of possible methods of achievement of the goals, considering designs of new solutions,
- assessment of positive and negative results of each variant of conduct with a risk map,
- comparison of variants according to various criteria and assessment enabling selection.

Due to an ambiguous meaning of efficiency, the method of its expression and measurement – in the new concept of increasing assets efficiency there are defined basic business areas affecting the production assets efficiency. Each element of assets efficiency is characterized by measurable qualities and the value of qualities changes over time. The area of efficiency is determined by the reference level of efficiency and the needs for efficiency assessment according to various criteria.

4.2 Areas of increasing production assets efficiency

The state of efficiency is reflected onto defined areas of efficiency:

$$\Omega = \{E_0, E_1, \ldots E_k\} \tag{9}$$

where: k = 1, 2, 3,... – the number of defined areas of efficiency.

Among defined areas of efficiency there areas: proposed (target), existing (effective), critical (unwanted):

$$\Omega^{\wedge} \cup \Omega^{o} \cup \Omega^{k} = \Omega \; \Omega^{\wedge} \cap \Omega^{o} \cap \Omega^{k} = \varnothing \tag{10}$$

An increase in production assets efficiency may be executed by changes reflected onto a certain designated area(s) in a set time, or countering the appearance of any unwanted state of efficiency from lack of changes.

The source of increased assets efficiency are: production stations, production units, a company as an organized production system.

Efficiency level	Efficiency criteria: Economic (economic efficiency)	Technological (technological efficiency)	Operating (operating efficiency)
Company ⇨	P -E_{ek}	P – E_{tech}	P - O_p
Production cell ⇨	K - E_{ek}	K – E_{tech}	K - O_p
Production station ⇨	S - E_{ek}	S – E_{tech}	S - O_p

Figure 5. Areas of increased production assets efficiency
(source: author's own work)

The following criteria were chosen for efficiency assessment: operating, technological, and economic.

$$E_m = \{E_{op}, E_{tech}, E_{ek}, R_j\} \quad (11)$$

where:
E_m – production assets efficiency,
E_{op} – operating efficiency,
E_{tech}– technical efficiency,
E_{ek} – economic efficiency,
R_j – relations for j = 1, 2, 3.

The areas of increased production assets efficiency are presented in Fig. 5.

Delivery of the main goal, due to the scale of problem, assumes determination of three levels of efficiency: 10 – company, 20 - production units, 30 – production station and three various criteria of assessment: operating, technological, and economic.

Each designated level of efficiency is a place for improvement of facilities and processes affecting increased efficiency. Rationality in the scope of methods and means of improvement is closely linked with the main goal.

The basic factors shaping production assets efficiency, upon assuming satisfaction of production needs are:

- production system development strategy,
- technique, i.e. the quantity and quality of technical means,
- technology of the manufacturing system,
- composition and structure of the manufacturing system,
- organization and management of the manufacturing process,
- conditions and interaction of the company with its environment.

Production assets efficiency is defined as a capability of technical facilities, comprising the production system, to fulfill set needs of a company in line with its destination and requirements. Requirements are usually divided into: structural, functional and development.

P. Sienkiewicz [49, p. 54] introduces a definition of efficiency of action systems – as a system feature, which expresses rational capabilities of systems for fulfilling certain needs (achievement of set goals of action, function with destination and requirements). Due to a time perspective the author distinguishes potential efficiency, upon assessment of whose only the needs and potential are considered.

Potential efficiency assessment ratio:

$$Fs(t) = \frac{Ws(t)}{Vs(t)} \quad (12)$$

where:
Ws(t) – needs,
Vs(t) – potential.

Assessment of potential system efficiency is an evaluation of the level of possibility of meeting a certain need, whose satisfaction is the goal of an entity. During an ex post assessment there is a notion of executed efficiency, which is a system feature characterizing the level of system's capability utilization in the process of delivery of certain goals and in set conditions. A division of areas of production assets efficiency is illustrated in Fig. 6.

Increasing efficiency is a process of constant improvement. Acceleration of routine processes often brings good results where it is a result of a project such as installation of more efficient machines and equipment. There are also opposite situations, where acceleration of operations results in delays and stoppages, and at the same time in lack of utilization of modern resources.

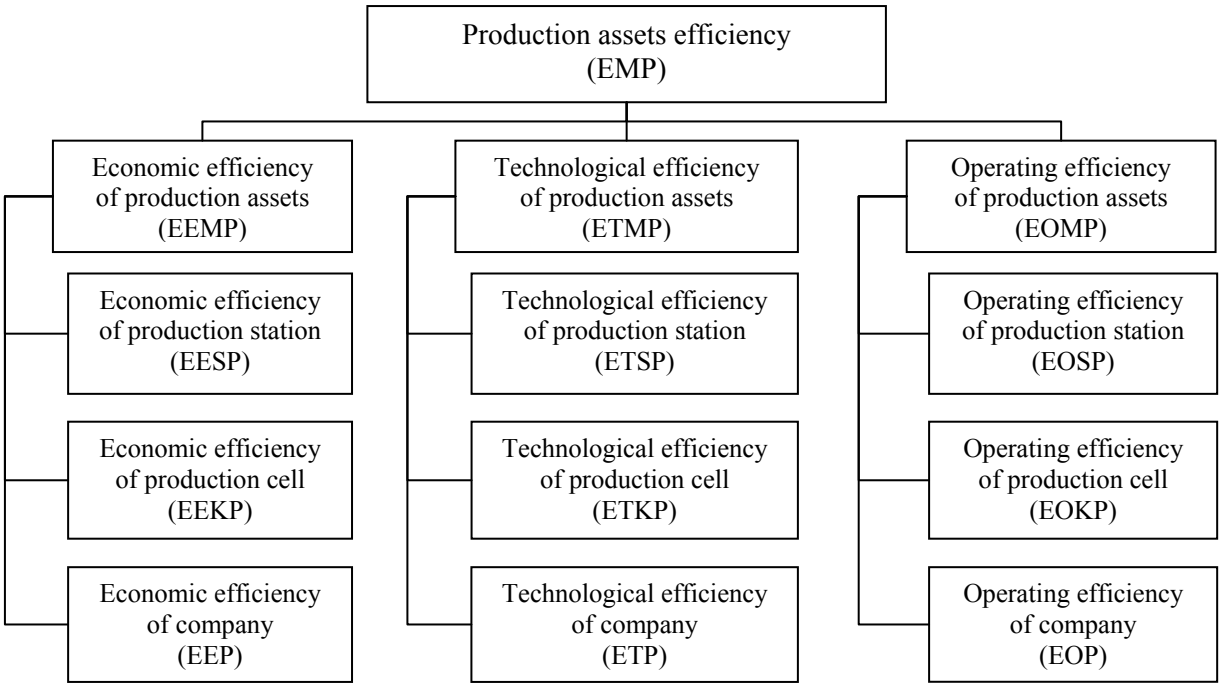

Figure 6. Division of area of production assets efficiency
(source: author's own work)

4.3 Basic methods of assessment of production assets efficiency

4.3.1 Division of assessment methods of production assets efficiency

The number of factors affecting assets efficiency, such as: fluctuations of orders from the market, technological advancement, new methods and techniques of production control, organization and engineering of exploitation and economic factors are the reason for search of new methods of assessment of production assets efficiency. The searched measures of assessment should be an efficient completion of a universal calculation of efficiency assessment.

The universal methods of efficiency assessment comprise:

- investment efficiency calculation,
- methods of efficiency assessment (including productivity),
- a group of ratios form financial statements.

A new concept assumes separation of three groups of assessment of assets efficiency:

- operating efficiency,
- technological efficiency,
- economic efficiency.

4.3.2 Operating efficiency of a production station (technical facility)

Operating efficiency of a production station is a feature expressing the ability of a technical facility to be in the state of efficiency of its elements and structures enabling delivery of set production tasks. The features of operating efficiency comprise: reliability, availability, lifetime. The scope of operating efficiency of a production station takes a form:

$$E_{op} = (N_z \cup W_d \cup W_k) \quad (13)$$

where:

N_z – reliability,

W_d – efficiency,

W_k – utilization.

a) Reliability of a production station

Reliability of any technical object is often described as quality over time (the characteristics of reliability as a feature of a facility – machine, equipment, set).

The following probability serves as the ratio of assessment of reliability [49]:

$$R(t) = \Pr \{T \geq t\} = \Pr \{\xi[x(t)], =1\}, \quad t \geq 0 \quad (14)$$

where:
T – is the moment of process X(t) entering into the set of inefficiency states;
ξ – the function of states:
$S^0 = \{ x \in X : \xi(x) = 1 \}$ – the state of inefficiency,
$S^1 = \{ x \in X : \xi(x) = 0 \}$ – the state of efficiency.

Durability – an ability of the facility to conserve its characteristics and parameters in applied exploitation conditions. For reparable objects durability is defined as the total time of facility work until resignation from its repair.

An indicator of durability of expected time of exploitation (e.g. calculated according to depreciation rate, set economic time of exploitation). The exploitation period is presented by function [41, p. 119]:

$$f: P * S * N * U \rightarrow T \quad (15)$$

where:
$P(p_1, p_2, ..., p_n)$ – the set of technical and exploitation parameters of a machine (technical facility),
$S(s_1, s_2, ..., s_n)$ – a set of parameters and size of the exploitation system,
$N(n_1, n_2, ..., n_k)$ – a set of size of expenditure and running costs of a machine,
$U(u_1, u_2, ..., u_n)$ – a set of parameters of technical advancement in construction and manufacturing technology.

In the T set there are following phases of exploitation: a period of liquidation, a period of exploitation resulting from lowest costs of machine operation, a period of exploitation dependent on the time of replacement of the current machine with a modern one. A signal for an analysis of operating efficiency of a facility is the period of exploitation at the time when the book value of a facility is zero.

Operating readiness:

$$Go(t,\tau) = G(t) * G(t, \tau) \quad (16)$$

where:
G(t) – initial readiness (ability to work), an ability of facility enabling its use without breaching the quality of executed functions,
G(t, τ) – task readiness, a quality of facility from the point of view of achievement of an allocated to the facility task. It means that the facility being in the state of work at the moment (t) will still be in that state at the time τ, in order to execute the allocated task.

Ensuring required operating readiness at possibly lowest costs may be put down in the form:

$$G_o(t,\tau) = G_o^w(t,\tau) \quad \text{at} \quad k_{ot} \rightarrow \min \quad (17)$$

or achievement of maximum operating readiness at set border costs of facility maintenance may be written in the form:

$$k_{ot} = k_{ot}^g \quad \text{at} \quad G_o^w(t,\tau) \rightarrow \max \quad (18)$$

where:
k_{ot} – facility management costs,
k^g_{ot} – border costs of facility management.

The first step in assessment of operating efficiency of a workstation is assessment of reliability of a technical facility in a complex approach, because reliability affect effective time.

b) Efficiency of a production station

Efficiency is an economic and operating measure of efficiency, considering the level of production reflected on the level of resources used for their production. Efficiency may be reflected on numerous levels of efficiency (company, department, workstation). R.W. Griffin [13, p. 621] distinguishes several forms of efficiency: overall efficiency (multi-factor) – overall productivity is defined in a formula:

$$\text{productivity} = \frac{\text{production}}{\text{expenditure}}$$

where:
expenditure – resources such as: labor, capital, materials, and energy used for manufacturing all products and services; and partial efficiency considering one category of resources, often defined of as labor efficiency, calculated from the relation:

$$\text{labor efficiency} = \frac{\text{production}}{\text{bnp}}$$

where:
bnp – direct labor expenditure (e.g. time of work).

Machine efficiency, determines the number of products manufactured by a machine in a given unit of time (usually one hour, or one shift).

Planned efficiency of a machine is achieved maximum production in ideal conditions in a given period of time (e.g. hour, shift, week) [56, p. 279]:

planned efficiency = production per hour * number of available hours

The planned efficiency is affected by the manufacturing task dependent on the variety and mass production.

Table 1. Division of states of use
(*source: [41, p. 128]*

Type of process	States of usage			
	S_1	S_2	S_3	S_4
Single state	Usage			
Two state	movement		Stoppage	
Two state*	work		idleness	

Effective efficiency of mass producing machine is maximum production achieved in the effective working time of the machine.

$$\text{effective efficiency} = \text{production per hour} * \text{number of available hours} * \text{operating readiness}$$

Effective efficiency, apart from production task, depends on the preparatory – completion time and technical time (maintenance, repairs, technical breaks). An increase in efficiency is possible, most of all, through employment of machines with high concentration of tasks in the manufacturing technology.

In designing rhythmical production effective efficiency is replaced with a notion of workstation production capability, set as a product of hourly production capability m_g and time T:

$$M_p = m_g * T \tag{19}$$

where:

$m_g = \frac{1}{t_j}$, t_j – time unit of a technological operation,

Hourly production capability increases when we perform a series of technological operations in an automated cycle.

c) Utilization of a production station

Utilization – the use of a workstation for a given production goal with a benefit for a given task. Division of states of use of production station is presented in Table 1.

The following may be differentiated in the set of usage states:

S_1 – state of effective work,
S_2 – state of idle work,
S_3 – state of stoppage work related to preparation of the effective work,
S_4 – idleness state.

$$U = \{S_1, S_2, S_3, S_4\} \tag{20}$$

Measures of assessment of usage state:

- time of station's usage state
  $T_u(t) = T_1(t) + T_2(t) + T_3(t) + T_4(t)$
- time of station's (technical facility's) movement
  $T_r(t) = T_1(t) + T_2(t)$
- time of station's work
  $T_p(t) = T_1(t) + T_2(t) + T_3(t)$
- time of station's stoppage
  $T_{pr}(t) = T_3(t) + T_4(t)$
- time of station's idleness
  $T_b(t) = T_4(t)$

The station's usage coefficient:

$$W_s = \frac{Tp(t)}{Tu(t)} \tag{21}$$

The station's load coefficient:

$$\eta = \frac{Tr(t)}{t} = \frac{Zg}{Mg} \tag{22}$$

where:
Zg – hourly task,
Mg – production capabilities.

The coefficient of workstation usage expressed in a different form [56, p. 279]:

$$W_s' = \frac{\text{real\_production}}{\text{planned\_efficiency}}$$

The station's load coefficient expressed in a different form:

$$\eta = \frac{\text{real\_production}}{\text{real efficiency}}$$

Calculation of efficiency and utilization of workstations is aimed at selection of the efficiency and usage levels for planned production tasks. Excess or shortage means too high investment in equipment, and shortage may lead to loss of potential sale of products or services.

4.3.3 Operating efficiency of a production cell

Operating efficiency related to production cells is a feature, which expresses capability of production cell for rational utilization of resources upon execution production tasks. The following are qualities of production units: efficiency, production capabilities, utilization of production capabilities.

The area of operating efficiency of production cell has a form:

$$E_{OKP} = (W_{KP} \cup Z_{PP} \cup W_{ZP}) \quad (23)$$

where:
W_{KP} – efficiency of production cell,
Z_{PP} – production capabilities,
W_{ZP} – utilization of production capabilities.

A production cell [11, p. 108] is defined as a relevant element of the production structure with separated particular factors of production, able to perform allocated production tasks.

The basic measure of organizational production units is the production capabilities.

The factors determining production capability are:

- the factors of production (means of work, subject of work, workforce),
- the scope of production and its structure,
- production organization and management,
- the disturbance to the balance between the supply and the demand and the market of suppliers and recipients,
- the investment policy.

In business activities of production companies the efficiency production units is interpreted as the efficiency of production capabilities. It results from the fact that means of work have a relatively stable and objective character and are considered basic factors of production capabilities.

a) Efficiency of production stations in a production cell

Efficiency of groups of uniform production stations (technological nest) id the total of efficiency of particular stations:

$$W_{NSP} = \sum_{i=1}^{n} W_i \quad (24)$$

where:
W_{NSP} – efficiency of groups of uniform production stations,
Wi – efficiency i^{th} production station , for i = 1...n.

Assuming that the efficiency of a station is the production capability of the station ($m_{g\,i}$):

$$W_{NSP} = \sum_{i=1}^{n} m_{gi} \quad (25)$$

The efficiency of groups of production stations, whose work and efficiency are interdependent by the flow of parts and components also depends on the structure of relations between stations in terms of reliability. There are three basis structures of relations: row structure, parallel structure, mixed structure.

Efficiency of group of production stations in a row and mixed structure depends on the stations with the lowest (leading) efficiency, the efficiency of a group of machines in parallel structure is decided by the sum of efficiencies of machines comprising its parts. Immobilization of one of the machines in the row structure decreases the efficiency of the group to zero. A stoppage of one of the machines in a parallel structure decreases the efficiency of a group of machines proportionally to their efficiency.

b) Production capabilities

Production capabilities determine the maximum number of products that may be produced within a set period of time. Production capability sets the real possibility of maximum utilization of machines and equipment and the production space, assuming rational utilization of other factors of production and manufacturing methods.

The measure of production capabilities [28, p. 378] is the ability to perform work in a set period of time, measured by work units. It is often expressed in the category of efficiency, i.e. the quantity of product produced in units of time.

The ratio method of calculation production capabilities is brought down to the relation between capability on the efficiency of workstations and the quantity of time set in a given period.

$$Z_p = \sum_{i=1}^{k} W_{gi} * F_{ei} \quad (26)$$

where:
W_{gi} – efficiency of group of production stations i (i = 1,2,...k),
F_{ei} – effective pool of work time of a group of stations i (i = 1...k).

Efficiency of production capabilities is expressed directly by:

- productivity, the level of production derived from the unit of resource,

- the level of utilization, the level of available production capabilities, which is really utilized.

For production nests at the stage of planning, hourly tasks are planned:

$$Z_g = \frac{P_{ri}}{F_e} \quad (27)$$

where:

$P_{r\,i}$ – a program of production of products i,

F_j – a planned pool of time of production stations in a cell j,

Z_g – hourly task of product output i.

Production capabilities of a production nest:

$$Z_p = Z_g * F_e \quad (28)$$

For a production line production capability is determined from the formula:

$$Z_p = \frac{F_e}{\tau} \quad (29)$$

where:

Fe – effective pool of time of workstations in a line,

τ – production tact.

Production capabilities of the area is determined from a formula:

$$Z_{ps} = F_e * S * W_{ps} \quad (30)$$

where:

Z_{ps} – production capabilities of the area,

F_e – effective pool of work time,

S – area of the production cells [m²],

W_{ps} – productivity coefficient 1 m² (pieces/ m²).

Control over the production capability is related to planning of needs in the scope of the quantity and the quality of production workstations.

Apart from a ratio based method of establishment of production capabilities one may use others [32, p. 44], such as: analytical method, normative method, or use methods of linear programming. Substantial extension of production capabilities requires appropriate investment in possible application of efficient means of work and processes, application of automation and shortening of introduction times (mass and flexible production).

c) Utilization of production capabilities

Utilization of production capabilities is an activity aimed at uninterrupted functioning of the production system. In fact, the activity is aimed at maintenance of production capabilities above such a level of utilization which enables functioning of the system at a variable level of production orders. The level of utilization often results from a set profitability level for the production system.

The function of utilization result takes a form:

$$W_{ZP} : W_E \text{ x } X_R \rightarrow R \quad (31)$$

where:

W_E – input (a set of production factors),

R – output (a set of products –reaction to production orders),

X_R – a set of regulations of production orders.

The following types of processes might be distinguished in the utilization process:

- determined,
- variable (slowly changing tendencies with seasonal variations),
- utilization dependent on highly variable conditions of business (mainly external).

Observation of the intensity of orders enables adequate planning of changes in the portfolio of orders for a determined and variable processes of utilization of production capabilities.

Utilization in a short time (month, quarter), upon assuming a determined process, is expressed by a relation:

$$W_{ZP} = \mu_W \cdot t_W \quad (32)$$

where:

μ_W – intensity of utilization of production capabilities,

t_W – the time of utilization of capability resulting from the load on workstations of production cell.

In recent years a lot of Polish companies have introduced TPM (Total Productive Maintenance) – a philosophy of increased productivity, based on maximization of the OEE-Overall Equipment Effectiveness).

The OEE ratio describes three areas of machine application in a production process defined in a formula ([27, p. 20], [51, p. 65]):

$$\text{OEE} = \text{availability of machines} * \text{eficiency} * \text{quality}$$

Risk and uncertainty affect the level of reserve production capabilities, which is a difference between planned production and the level of manufactured production in a company:

$$R_{ZP}(t) = [Z_{PP}(t) - P_W(t)],* W_{ZP}(t) \quad (33)$$

where:

$R_{ZP}(t)$ – production reserve in period t ($t = \tau_1, \tau_2, \ldots \tau_k$),

$Z_{PP}(t)$ – planned production capabilities in period t ($t = \tau_1, \tau_2, \ldots \tau_k$),
$P_W(t)$ – the level of manufacture production in period t ($t = \tau_1, \tau_2 \ldots\ldots \tau_k$),
$W_{ZP}(t)$ – the level of effective utilization of production capabilities in period t ($t = \tau_1, \tau_2, \ldots \tau_k$).

The basic goal of examination of production capabilities reserves [32, p. 52] is a possibility of increased production without increasing production potential. In business activities reserves are divided into two groups:

- intensive reserves, resulting from a need for increased efficiency of machines and equipment,
- extensive reserves relating to a possibility of increasing the time of work of means of work and loan on the production area.

Production capabilities and their utilization is a reflection of quality, precision, and ensuring long-term efficiency with continuation of innovation, utilization of technological position on the market and maintenance of production in highly profitable countries.

4.3.4 Operating efficiency of a company

Efficiency was set as the main operating criterion at the level of company, i.e. the ability to reach the set goal of final activity.

One may assume that effectiveness, or efficiency is defined as the level of compliance between results and goals of activities.

R.W. Griffin [13, pp.127-128], distinguishes following models of organization efficiency:

- system – resource approach (concentration on resources, which an organization may secure for itself in business),
- target approach (selection of targets and their subsequent achievement),
- approach from the side of internal processes (product supply chain),
- strategic electorate approach (concentration on groups interested in the success of the organization, e.g. producer – suppliers, entity – banks).

Achievement of efficiency of production assets in an operating cycle requires efficient production management.

a) Efficiency of goal realization

Efficiency is referred to the level of execution of tasks adopted for the production system. Efficiency is a function of both production capabilities and the particularities of the task itself in the form of orders for particular products and services. Orders appearing in a company may be determined, random, or unknown (product not produced in the company).

Depending on the method of determination of the final goal there are staged and non-staged goals. In the case of production business results of business are more or less close to the main goal. If the main goal is achievement of a sales plan then the scope of assessment of execution level covers criteria such as: punctuality, quality, costs. From the client's point of view the first two criteria are important (assuming that the agreed price is not staged).

Example – Gradation of results of sales plan achievement in the aspect of timeliness and quality:

0 – delays in achievement (punishable),
1 – delays in achievement (agreed),
2 – lack of delays in achievement.

Timeliness T = (0, 1, 2), for:

0 – means lowest level,
1 – means middle level,
2 – the highest level.

Similarly for quality:

0 – reports on product damage of high importance in the period of warranty (product unfit for use),

1 – reports on product damage of low importance in the period of warranty (product fit for use),

2 – no reports on product damage in the period of warranty.

The level of efficiency of achievement of the plan of sales in the aspect of timeliness and quality is presented in Table 2.

Table 3 shows that highest priority in efficiency of achievement of the sales plan is timeliness (no delays in achievement) and quality (no reports of damages in the period of warranty). In numerous cases of achievement of the sales plan quality is of higher importance than timeliness. It means that item 4 in Table 3 is positive (grade – partially efficient*).

One may ask a question whether undertaking delivery should fulfill requirements of minimum efficiency in a form of efficiency point?

Table 2. Efficiency level of achievement of the plan
(*source: author's own work*)

No.	Timeliness	Quality	Goal achievement level	Delivery efficiency level
1	2	2	9	Efficient
2	2	1	8	Partially efficient
3	2	0	7	Inefficient
4	1	2	6	Partially efficient *
5	1	1	5	Partially efficient
6	1	0	4	Inefficient
7	0	2	3	Partially efficient
8	0	1	2	Inefficient
9	0	0	1	Inefficient

Table 3. Levels of goal achievement
(*source: author's own work*)

No.	Timeliness	Quality	Goal achievement level
1	2	2	4
2	2	1	3
3	1	2	2
4	1	1	1

On the basis of data from Table 4.3.4b one may assume:

- efficiency point = min{timeliness=1; quality =1},
- number of stages in the goal = 4.

Excluding from columns (2) and (3) value weights = 0, the result is a reduced Table 2.

From Table 3:

- minimum efficiency - goal achievement level: c = 1,
- efficiency point - goal achievement level: c_{min} = 2,
- full efficiency - goal achievement level: c = 4.

b) Efficiency of cooperation of production cells in an operating cycle

Efficiency of cooperation

$$\text{KP} = (\text{effective time: real time}) * 100\% \quad (34)$$

The management of production cells must be adjusted to the characteristics of the production process. Spatial structures of production cells, meeting the criteria of rational deployment, will show following advantages [40, p. 180]:

- shortening of total production cycle and decrease in its costs (reduction of obsolete relocations, reloading, and manipulations),
- maintenance of the quality level of products and more efficient production methods.

Studies in numerous companies with mass type of production [48], indicated efficiency of cooperation of production cells at the level of 75 – 80% (Fig. 7). The flow of the process in cells of subject structure takes shorter time than in units of technological structure.

c) Efficiency of production assets facility maintenance

In traditional approach the measure of efficiency is the effective time of machine and equipment work available in the management of production capability. In a temporary approach, efficiency of facility maintenance is assessed on the basis of utilization of micro organizational breaks in the production process for maintenance and repair of machines and equipment assuming periodical maintenance breaks.

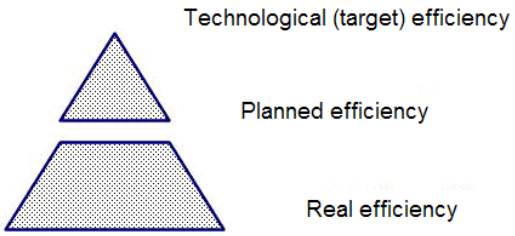

Figure 7. Division of efficiency of a workstation
(*source: author's own work*)

Other ratios are:

$$\text{Achiewement Ratio UR} = \frac{\text{possibility of achievement: tasks to be performed}}{} * 100\%$$

The ratio is a consequence of applying the economy rule in measure in the management of production assets.

4.3.5 Technological efficiency of a production station

Technology is the source of progress and increase in efficiency, affects the time of manufacturing – an important category in the process management. Time is an important factor of companies' competitiveness and may be utilized by: shortening of processes (timesaving), changes of existing processes to new ones (flexibility of time).

a) Technological efficiency of a production station

Technological efficiency – maximum achievable number of products at the output of process in ideal technological conditions (target efficiency of a production station)

According to SANDVIK company [60], proper application of tools (made of new tool materials) is able to improve efficiency by at least 20% due to higher speed of cutting and headway. Another benefit is higher quality of machined details (parts), a limited amount of waste and lower machining costs.

Increase in efficiency due to smoothing plates (an innovative product) is possible as a result of a small change to the corner of the plate, the speed of headway may be doubled while maintaining the finishing of the surface.

b) Production flexibility

Flexibility is associated with the ability for fast changes in processes enforced by the market. Mass production in, so called, „rigid" technical and technological systems does not meet the expectations of the market, which expects large selection of products produced in small batches and more varies expectations of clients.

According to J. Honczarenko [15, p. 224] technological flexibility of a lathe, in relation with the flexibility of the control system and flexibility of supporting equipment, comprises production flexibility of manufacturing systems. Production flexibility is a quality of a workstation expressing its ability to relatively easy and fast re-tooling and change of controls onto new products manufactured in small and varied series. An extended scope of manufacturing capabilities leads to machining products into ready-made items.

Production flexibility may be expresses as a quantity – by the number of various products, details, or production tasks, and qualitatively – sometimes transferring from the delivery of one task onto the other. There may be real and potential production flexibility. Benefits of a higher production flexibility are characterized by shorter times and an increase in real efficiency of workstations.

c) Automation of the processes

Automation contributes to the intensification of the manufacturing processes and leads to significant improvement in the technological level in all the elements of the process. The basis for improvement in efficiency resulting from automation is implementation of modern CNC production stations and technological processes. The development of automation on traditional technological processes would not result in improved efficiency. Automation plays an important role in better control of the time period [34, p. 59]. Shorter periods of time between orders from client to delivery of a ready product conditions efficient production.

Shortening of single process times, by concentration of tasks in a workstation leads to 5, or 6 fold increase in the station's efficiency.

Technological efficiency, production flexibility and automation of processes do not involve adjustment to changes only, but also utilization of their capabilities in order to utilize the modern market, which is difficult to recognize.

4.3.6 Technological efficiency of production cell

a) Efficiency of influence of technology on efficiency of production cell

Development of technology results in a possibility of decreased work consumption, and, as a result, in lower costs, and increased productivity of production stations of cell. The ratio takes a form:

$$S_{OTW} = \frac{\sum_{i=1}^{n} \Delta t_{j1} + \Delta t_{j2} + \ldots \Delta t_{jn}}{T} \quad (35)$$

where:

S_{OTW} – efficiency of influence of technology on efficiency,

$\Delta t_{j1}, \Delta t_{j2}, \ldots \Delta t_{jn}$ – decrease in work consumption in stations 1,2...n,

T – period of time (month, quarter, year).

A change in technology may comprise: the type of material, state of surface machining, shape, tools, equipment and process parameters. A decrease may affect not only the main time, but also the auxiliary time. In a longer period of time, lack of lower work consumption is a proof of low efficiency of influence of technology on efficiency.

b) Efficiency of settings and control of processes

The time of settings may be a productive time. Manual toll and object fitting on the stations and their control are time-consuming, non-repetitive activity, prone to errors of the operator. Technologically advanced machines are the source of income only when they work. An increase in productivity and accuracy requires reduction in stoppage times. It is possible as a result of application of measurement probes.

Application of measure probes eliminates the need for use of auxiliary equipment (costly special holders, measurement gauges). The measurement of the first piece in a production series, performed by manual meters, depends on the skills of the operator, however, the machined item's transfer onto the measuring machine may take a lot of time. Probes are able to control parts in the lathe in a shorter time.

Software of probes automatically compensates for deviations in the length and diameter of tools, the location of the part, and dimensional errors.

$$\frac{t_{ui} + t_{ki}}{t_{uo} + t_{ko}} < 1 \quad (36)$$

where:

t_{ui}, t_{ki} – setting and control time using modern measure tools,

t_{uo}, t_{ko} – setting and control time using traditional measure tools.

Systems of measurement probes enables elimination of costly stoppage time, particularly in CNC lathes and machining centers. Due to measurement systems of probes the setting and control time may be shortened by over 90% and increase the machining efficiency.

c) Utilization of technical diagnostics equipment

Technical diagnosis deals with assessment of the state of machines and equipment through direct examination of their qualities and indirect assessment of utility processes performed by them.

The purpose of utilization of technical diagnosis devices is reduction in stoppage time of production machines. The reasons for decreased technical state of machines are: post control faults, defective parts, loss of productive time, decreased efficiency, lower quality.

An important effect of utilization of technical diagnostics is the creation of basis of preventive maintenance and repairs.

The areas of utilization of diagnostic tools:

- verification of technical state of machines,
- classification and comparison of machines,
- testing and monitoring of the state of machines,
- forecasting necessary maintenance,
- checking new machines during sign-off examinations.

Facility management of machines with different wear structure requires utilization of technical diagnosis tools. Fast diagnostic assessment of the technical state of machines and equipment is the source of reduced stoppage time and maintenance costs, enables creation of planning preventive maintenance services.

4.3.7 Technological efficiency of a company

a) Efficiency of alternative technology development

Technology is a process of joining various types of resources in order to manufacture products which satisfy market needs. Basic resources comprise:

- technical resources (machines and production equipment),
- technological resources (technological knowledge, programs, projects of operating processes, possession of know-how),
- personnel resources (awareness of existence of alternative technology and readiness for their implementation, qualifications and competence of personnel).

Factors determining technological and personnel resources are cumulated. In division of manufacturing processes there are following criteria: type of process, technology and technological means applied during the manufacturing and organization of the process.

I. Durlik [11, p.148] claims that technology is not a constant category and is subject to constant development; it applies to used materials, tools and equipment, utilization of devices, methods of transport, methods of measurement and testing of products and method of maintenance.

In conditions of alternative technology it is advisable to assume that technical resources are adjusted to planned tasks, which determine needs resulting from influence of such factors as: efficiency, quality and time.

The basic criteria of alternative technology selection are usually: work consumption, material consumption, energy consumption, capital consumption.

Attractiveness of alternative technology results from the fact of elimination of simple works in favor of works requiring educated, skilled employees. The potential of alternative technology is reflected in a possibility of increased productivity, increased quality of products and processes, and also in decrease in costs.

Technological efficiency at the level of company comprises not only technical resources but the whole of technology. P. Drucker [9, p. 34], stresses that every technology is a system of concept and its technical aspects are rather the effect not the reason.

The technological effects of new solution are:

- an increase in the efficiency of a process due to a possibility of utilization of production machines with high concentration of operations,
- ensuring stable quality of products in the manufacturing phase,
- an increase in the efficient time pool of machine and equipment work,
- a shorter cycle of delivery of production orders,
- a possibility of utilization of production flexibility.

An example of technological efficiency is the concept of flexible manufacturing of EROWA company [59], for rational and future-oriented organization of unit and small batches production.

Influence of the level of automation upon utilization of lathes is presented in Fig. 8. There are numerous alternative technology solutions, including resignation from operations with low added value toward producer with higher technological level, or limitation to assembly with parts and components purchase from companies considered credible in terms of meeting technological and economical criteria.

b) Technological efficiency of processes development

Utilization of Advanced Manufacturing Techniques (AMT) requires efficient design of processes. Transfer from conventional production machines to numerically controlled meets limitations of software of technological processes. In this elaboration's author's opinion the efficiency of designing in Polish companies according to AMT criterion is at the level of about 50%.

c) Efficiency of knowledge and technological experience

Modern technology, except technology directly related to utilization of production assets, also covers knowledge, know –how, and experience cumulated in the process of human work. This technology part is described as immaterial technology [29, p. 383]. Knowledge and experience become an important advantage in international cooperation of companies.

In Polish companies immaterial technology is undervalued which results in falling productivity of numerous applied technologies. In numerous organized joint – venture companies technology is the value contributed to the share capital of the company.

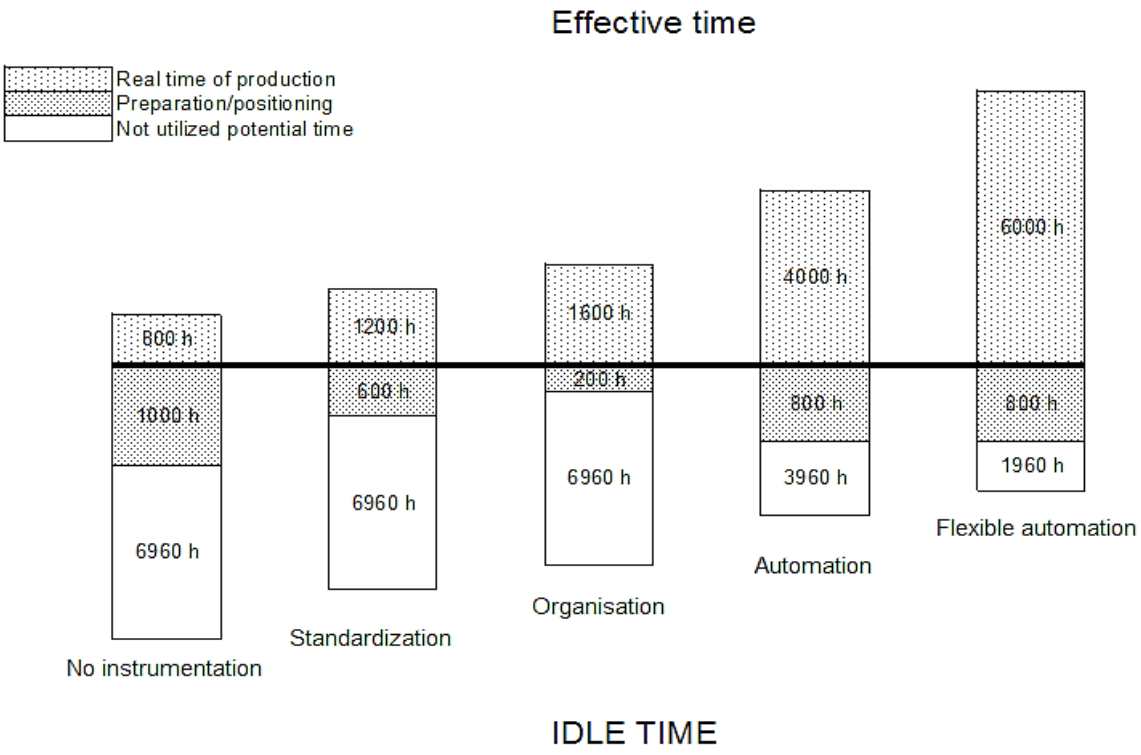

Figure 8. Annual utilization of lathes for various levels of automation
(*source: [15, p. 25], [59]*)

4.3.8 Economic efficiency of production assets at the company level

a) Overall and partial productivity

Assessment and improvement of productivity in the economic aspect productive utilization of all resources used in manufacture of products for the market requires supervision. P. Drucker [9, p. 57] assesses traditional ratios reflecting productivity as unclear and imprecise. According to the author, the most important factors for productivity are: time, composition of the production profile, composition of the production process and the organizational structure of the company.

Productivity – is a proportion of the production volume and sold in a given period to the quantity of used or utilized resources. This measure is to be interpreted as efficiency of utilization of resources of the production system. The productivity measures are divided into two groups [37, p. 31]:

- overal (general) productivity – the proportion of the total production to the total amount of used or utilized resources for their manufacture,
- partial productivity – the proportion of the total production to the amount of particular kinds of resources to the total amount of used or utilized resources for their manufacture.

b) Profitability of assets (ROA)

$$\mathrm{ROA} = \frac{\mathrm{net\_profit}}{\mathrm{total\_assets}} * 100\% \tag{37}$$

c) Ratios of investment in alternative technologies (technical and technological resources)

$$\mathrm{I_{AT}} = \frac{\mathrm{N_{AT}}}{\mathrm{P_{SP}}} * 100 \tag{38}$$

where:

N_{AT} – expenditure on investment in alternative technologies,

P_{AT} – revenues from sales of products.

Economic efficiency of assets at the company level, presents efficiency measured by productivity, profitability of assets and intensity of investment in alternative technologies.

4.3.9 Economic efficiency of assets of production cells

a) Efficiency of investment projects in alternative technology

Planning and delivery of investment products is related to a decision about purchase or manufacture of new assets, mainly of technical and technological resources. Methods of assessment of investment projects belong to the group of universal methods. Economic assessment involves an analysis and assessment whether the project multiplies invested capital and whether the rate of multiplication is high enough in the investment calculation period.

Universal methods include the following efficiency criteria ([7], [33] and [42]):

- the period of return of expenditure,
- book rate of return of expenditure,
- net revaluation value criterion,
- other (profitability ratio, IRR).

Developed methods of investment efficiency assessment are based on discount techniques. An example is the criterion of Net Present Value (NPV).

The concept of Internal Return Rate (IRR) involves determination of annual rate of multiplication of capital invested in a given project. It is a clear measure for an investor.

b) Labor costs of workstations in a production cell

The formula of cost calculation for one workstation ([55, pp. 73-81], [40, pp. 39-47]) lists in detail particular elements of fixed and variable costs.

$$K_{SP} = k_z + \frac{K_S}{F_{ef}} \tag{39}$$

where:
k_z – variable costs of a workstation,
Ks – fixed costs of a workstation,
F_{ef} – pool of time of a workstation.

The costs of a workstation decrease with higher charge with production tasks.

c) Economic efficiency of maintenance of production stations in cell

General formula takes the form:

$$E_{UR} = \frac{\text{actual expenditure}}{\text{planned expenditure}} \leq E_{URmax} \tag{40}$$

Actual and planned expenditure considers costs borne on maintenance, preventive and repair activities in a set scope.

4.3.10 Economic efficiency of a production station

a) Current value of a production station

- Net value

Net value (book value) = gross value – depreciation value

- Replacement value

Determined upon technical identification of facility or documentation and current prices of catalogue objects. The general formula takes the form:

$$\text{replacement value} = \text{Wb}\left(1 - \frac{Z_F}{100}\right) \tag{41}$$

where:
Wb – gross value according to catalogue prices of a facility compared with the valued facility,
Z_F – physical wear of facility (%).

- Market value

Value of technical object achievable on the industry market. The general formula takes the form:

$$\text{market value} = \text{Wb}\left(1 - \frac{Z_F}{100}\right)\left(1 - \frac{Z_E}{100}\right) \tag{42}$$

where:

Z_F – physical wear of facility (%).

Z_E – economic depreciation of facility (%).

The comparison of the values gives a view over the fall/increase in the useful value and its influence on quality and timeliness of production.

b) Economic efficiency of increased efficiency of a production station

An increase in efficiency of a station results from a need for achievement of production tasks. Factors affecting efficiency are: technical facility, tools, devices, measuring equipment, parameters of a work process, facility operator. The reference point is the stability of particular operations. Each operation with technical and organizational flaws of resources that execute it is potentially unstable, threatening a drop in efficiency and decreased quality of production.

The following formula of machine and equipment efficiency ratio OEE, may be used for establishment of economic efficiency of increased efficiency ([27, p. 20], [51, p. 56]):

$$\text{OEE} = \text{availability} * \text{efficiency} * \text{quality} \tag{43}$$

The schedule of the painting and anti-corrosion process of car bodies

The main process comprises main following, subsequent operations (activities):

1. transport with possibility of temporary waiting
2. preparation of bodies for chemical processing and chemical processing of bodies
   a) spray washing,
   b) submerge washing,
   c) activation,
   d) phosphatizing,
   e) passivation,
   f) submerge and spray washing,
3. transport of bodies to cataphoretic unit
4. cataphoretic submerge painting
   a) spray washing I and II
   b) submerge rinsing in demineralized water
   c) spray washing with demineralized water
5. transport of bodies to cataphoretic drier
6. drying and cooling of cataphoretic coat
7. transport of bodies from cataphoretic cooler with waiting capability (storing of bodies)
8. storage after cataphorezis
9. cataphoretic processing cabin
10. transport of bodies to the sealing cabin
11. joint sealing cabin
12. mastic spray cabin (PVC)
13. mastic coat drying and cooling (PVC)
14. transport and preparation of bodies for priming paint spay
15. electrostatic priming coat spray cabin
16. priming coat drying
17. transport of bodies from priming drier
18. priming coat cooling
19. transport of bodies from priming cooler
20. priming processing cabin
21. transport to the base cabin
22. electrostatic spray of base coat cabin and intrazone base drying
23. colorless paint spray cabin
24. colorless paint coat drying
25. transport of bodies from paint drier to inspection cabin with possibility of storage of bodies
26. inspection cabin
    a) inspection,
    b) polishing and minor repairs,
    c) polishing of bodies
27. transport of bodies from inspection cabin to assembly

Auxiliary process

28. transport of bodies to touch up cabin
29. touch up body preparation cabin
30. manual base spray cabin
31. intrazone base drying
32. manual clear lacquer spray cabin
33. clear lacquer coat drying and cooling
34. transport of bodies to inspection cabin

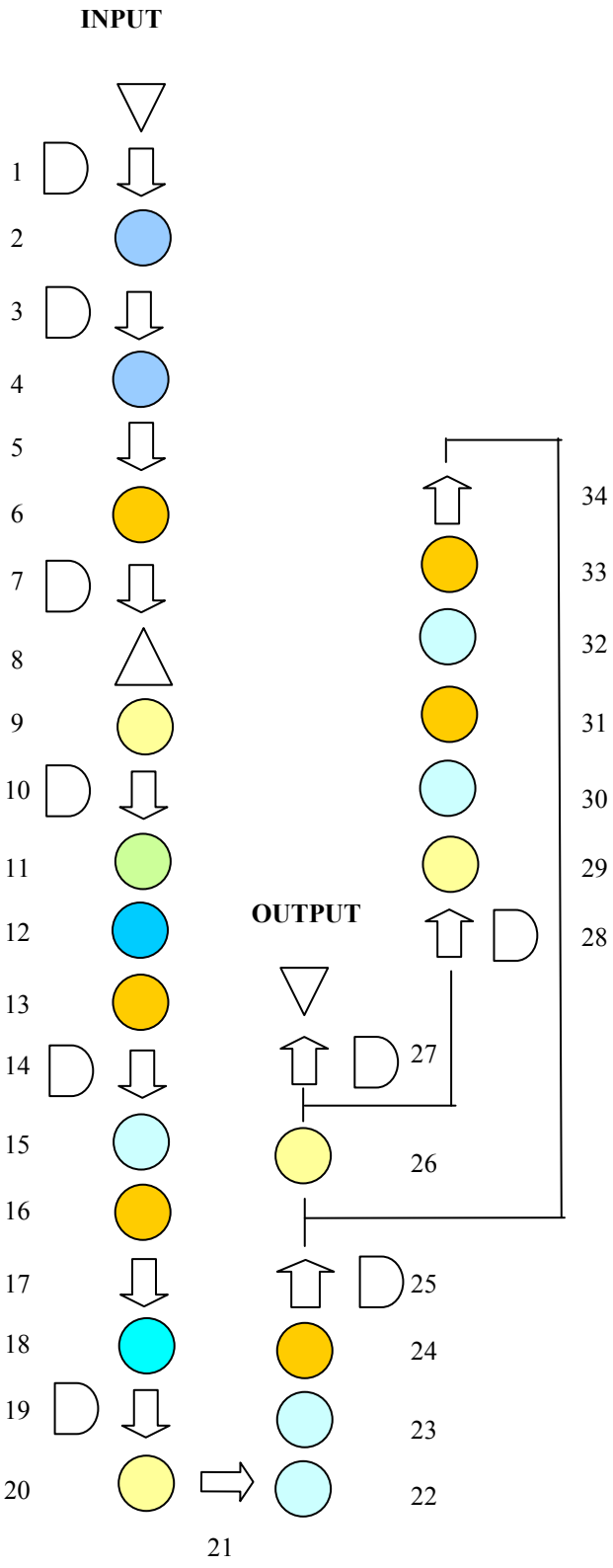

Figure 9. Scheme of painting and anti-corrosion car body process (*source: [58]*)

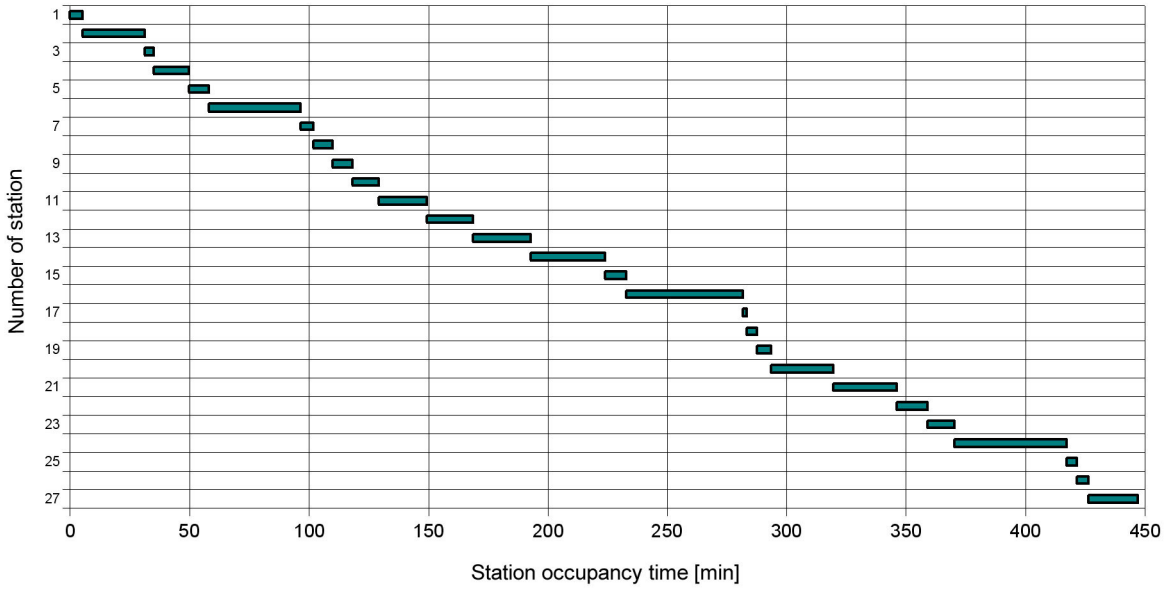

Figure 10. Schedule of the process of painting and anti rust of bodies
(*source: [58]*)

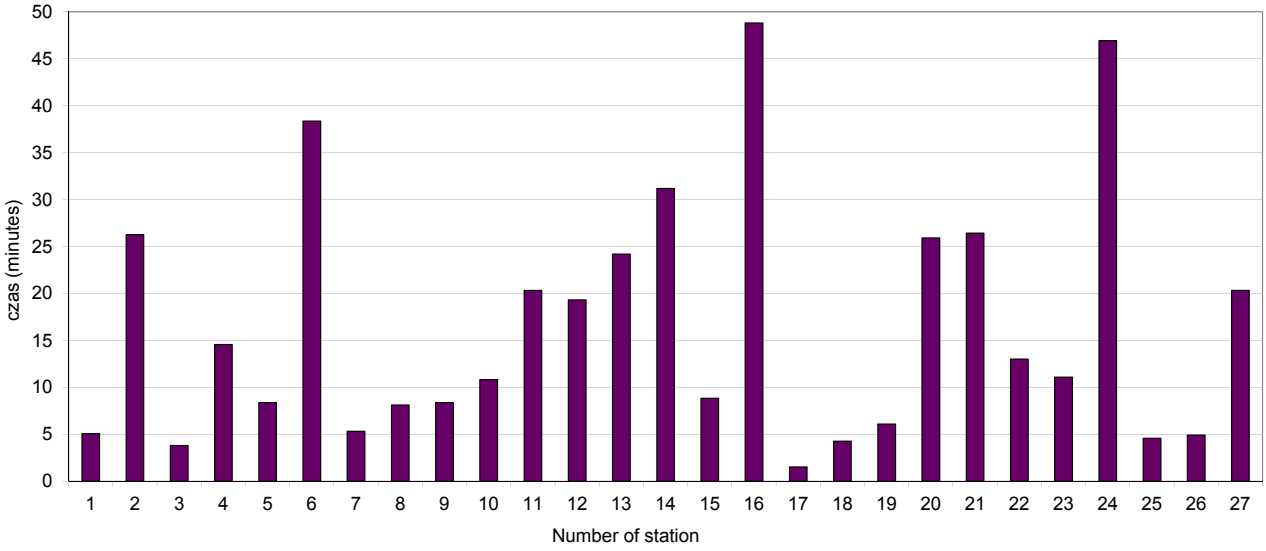

Figure 11. Distribution of workload on body painting and anti-corrosion line stations
(*source: [58]*)

c) Economic efficiency of alternative production station

The search of alternative solutions results from a need of decreased production costs. Such solutions comprise:

- stations outside the company,
- purchase of a new machine (a machining center instead of a CNC lathe) with modern production equipment,
- radical change in the technology of manufacturing.

The economic calculus in this type of ventures is one of traditional methods of assessment of economic efficiency.

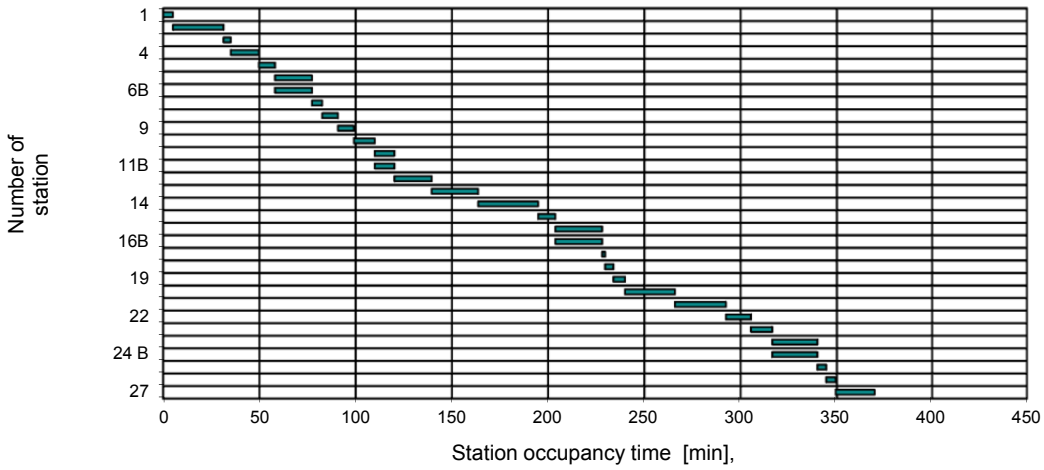

Figure 12. Schedule of the painting and anti-corrosion protection process with parallel running of coat drying operation
(*source: [58]*)

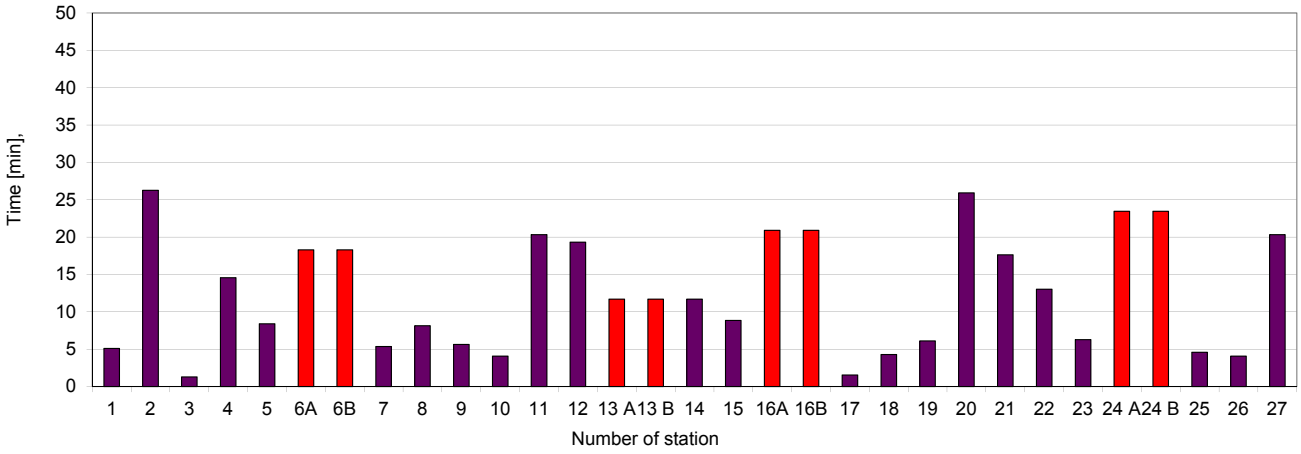

Figure 13. Distribution of load on workstations of the body painting and anti-corrosion protection line with parallel stations of coating drying
(*source: [58]*)

4.4 The project of production process improvement

The project of process improvement is designed to optimize the technological process in the view of meeting current technological, technical, environment protection, safety, and in particular, economic requirements.

The scheme of execution of the painting and anti-corrosion protection process of car bodies is presented in Fig. 9 and Fig. 10.

The technological process is delivered on a production line in a continuous manner. The technological speed is adjusted for every station.

An important goal is an increase in the efficiency process. The schedule of painting and protection process is presented in Fig. 10 and Fig. 11.

The cycle of the process is 446 minutes. The distribution of load on stations is uneven (Fig. 11). Stations no. 6, 16, 24 are the critical knots in the process. In order to shorten the painting cycle it is proposed to run parallel stations of drying: coating, primer, and sealer, and application of sealers.

A new schedule is presented in Fig. 11 and Fig. 12. The time of production line filling is about 370 minutes. In car production conditions it is a significant shortening of time.

Distribution of load on painting and anti-corrosion protection workstations with parallel stations is presented in Fig. 12 and Fig. 13. One must remember that without drying a proper lacquering surface will be created.

In order to balance the continuity of the process and compensate for differences in speed of conveyers, one must use the intra-operation storages.

In order to further improve the body painting process one must look for new technological materials which may affect the drying time, and as a result, increased efficiency.

5 Summary

Production assets management in a company is a traditional function, which in the period of transformation lost its parallel role toward the marketing and finance function. Higher machine efficiency contributes to improvement of work efficiency. Production assets efficiency is limited to the economic criterion, often seen in business only in the statistical dimension.

Experience of exploitation of advanced productions systems indicates that the factor decisive of efficiency is available time, not exploitation costs.

A new concept of studies on efficiency results from adoption of an assumption, that development of production systems, including technology production, conditions production assets efficiency.

The main goal of the new concept is increased production assets efficiency in a company.

Achievement of the main goal, due to the scale of problem, assumes separation of three levels of efficiency: 10 – the company, 20 – the production cell, 30 – the production station, and its three different assessment criteria: economic, technological, operating.

At the level of production station operating efficiency has the following elements: reliability, efficiency, utilization of the production station.

A measure of operating efficiency of production cells are the ratios: efficiency of production stations, production capabilities, utilization of production capabilities.

The basic measure is the production capabilities.

Efficiency was selected as the main operating criterion at the company level, i.e. the ability to reach a set goal of the final activities.

Technological efficiency at the level of the production station is expressed by the ratio of technological efficiency, at the level of production cell the efficiency of technology influence on efficiency of production cell. At the company level, the alternative technology development ratio was taken.

Economic efficiency is determined by the factors: at the workstation level – economic efficiency of alternative production station; at the level of production cells – economic efficiency of designing alternative technology; at the company level – total and partial productivity.

The evolution of structural changes in Poland positively affected the efficiency of companies and the privatization process also covered production assets. Investment and modernization expenditure spent on production assets, contributed to implementation of modern technology and increased efficiency and the quality of the production process.

A new concept of study on production assets efficiency in a company results from development of technology and production systems. Gradual implementation of new technologies and modern processes of manufacturing products requires in companies requires increasing production assets efficiency.

The evolution of studies on the fixed assets management efficiency there are three periods:

- fixed assets management efficiency (years 1970 - 1989),
- restructuring of the non-current assets (years 1990 - 2000),
- fixed assets management (from 2000 and now).

The process of utilization of fixed assets is limited by technological efficiency and stoppages caused by various reasons.

A significant role of financial statements in Poland after 1990 and new importance of non-current assets as a part of company value, contributed to an analysis and assessment of new ratios of efficiency.

In a new concept of studies on production assets efficiency there are:

- operating efficiency,
- technological efficiency,
- economic efficiency

defined at the level of a production station, production cells, or a company.

The main goal of the new concept is to increase the production assets efficiency. Increasing the production assets efficiency is burdened with the technical and market risks. The rate of exchange of production machines depends on the lifetime of the technology. Efficiency measurement is an instrument of supervision, but a tool supporting management in the company.

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