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Research Results / Резултати от научни изследвания

STUDY OF THE KEY FACTORS INFLUENCING THE EFFECTIVE PLANNING AND UTILIZATION OF PRODUCTION FACILITIES IN THE INDUSTRIAL ENTERPRISE

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Abstract. In the modern world, the development of technology, machinery and equipment follows a rapid upward trend of constant innovative solutions. The problem of efficient planning and utilization of production capacity is also evolving. The question of knowing the factors affecting the development of production, which acquire other dimensions, closely related to the optimization of processes and activities and more efficient use of the main means such as machines, equipment, information technologies, etc., is increasingly relevant. The relevance of this problem is also determined by the increased integration of production technologies and the search for ways to apply flexible organizational forms for more efficient use of the equipment's capacity. The changes introduced in the era of Industry 4.0 are now irreversible, and the time has come for the transition to Industry 5.0. Behind Industry 5.0 are technologies representing a set of complex systems, and each of the categories can realize its potential only if it is combined with the others. Industry 5.0 can be seen as a new philosophy of business, according to which technology should work for the benefit of people and society. Business organizations must further adapt to exploit the capabilities of technology and combine them with those of people in order to develop effectively, sustainably and safely. New business models are needed, which require investing less funds and resources to obtain greater benefits. Industry 5.0 means optimizing human productivity and efficiency.

Taking into account these new trends that are rapidly emerging in the global business environment, this research is aimed at developing a research model of the key factors affecting the effective planning and utilization of production facilities in the industrial enterprise, based on the results of a previous study. A model is proposed to investigate the relationship between identified key factors and capacity management based on interpretive structural modeling.

Keywords: efficient planning; production capacity; AHP method; production organization; flexibility

1. Introduction

The industrial sector of a country is always the subject of increased attention and interest by part of researchers and analysts, as industry stands at the foundation of any economy. In this regard, the aim is to identify and outline those factors, prerequisites and conditions that enable enterprises and companies located in limited business environment, to compete successfully as on both domestic and international markets. (Minkov et al. 2019). Understanding, effectively planning and managing production capacity allows any organization to assess its future financial performance and create a reliable schedule for delivering products to its customers. The choice of an approach to the improvement and development of the production capacity is of utmost importance for the effective functioning of the entire production system of the industrial company. The study of the factors affecting the effective planning and management of production capacity is part of a unified strategy for the development of the entire enterprise. Changes in resource flexibility and resource location should be assessed against the spare capacity resulting from these changes. and a number of factors that increase or decrease the company's risks. These factors that affect production capacity are related to such a level that a change in one factor potentially affects others. No system can operate at full capacity for a long period of time. Inefficiencies and delays make it impossible to achieve the maximum theoretical production level in the long run. Without planning the use and increasing the production capacity of the enterprise, all business achievements of the production complex will be short-term. Capacity planning requires management to identify, analyze and monitor the key factors affecting organizational performance. (Dimitrova, Panayotova, Veleva 2021). Competencies in the field of teamwork, leadership and management play an important role in making management decisions. It is for professionals of all qualification levels to demonstrate a socially responsible attitude and ethics of the profession and the organization. (Dragozova-Ivanova 2015).

The main objective set in this scientific research is to investigate the key factors in the process of planning and managing the production capacity of the industrial enterprise.

Main tasks to achieve the set objective:

1. Determining the constraints and factors in making decisions relating to production capacity;
2. Determining the relationships between the key factors most influencing the functioning and management of production capacity in industrial enterprises.
3. Determining the significance (priority) of the determined factors.

Subject of research: the interrelationships and conditioning between the various factors that contribute to the construction and operation of the concept of optimal planning and management of production facilities.

Object of research is the production system of the industrial enterprise.

This publication presents a generalized research model of the key factors influencing the effective planning and utilization of production facilities in the industrial enterprise, based on the results of a previous study. The model includes two stages developed in the following technological sequence:

First stage

This stage performs the following tasks:

1. Identification of key factors affecting effective planning and management of production capacity.
2. Study of the relationship between the identified key factors and capacity management, based on the Interpretive structural modeling (ISM) method and organizational coordination model in parallel engineering;
3. Analysis of the relationships between the studied key factors using the Structural Self-Interaction Matrix (SSIM) and their classification into 4 main categories: independent, dependent, interdependent, governing;
4. Development of a structural model of the interaction of these key factors.

The model is based on ISM (interpretive structural modeling), considered in the scientific research of many authors. (Attri, Dev, Sharma 2013), (Bartels, Peters, Pruyn, van der Molen 2010), (Behl, Pal 2020). ISM is a method to identify inter relationship among various factors.

The analysis of the results of the completed survey of practices in 10 real machine-building enterprises led to the identification of 18 factors influencing the processes related to the effective planning and management of production capacity.

Factors playing a key role in the planning and management of production capacity:

F1 – Commitment of top management
F2 – Corporate and production strategy
F3 – Resource planning
F4 – Planning and effective management of production capacity
F5 – Level of production organization
F6 – Mechanization and automation of production
F7 – Degree of efficiency of use of production equipment
F8 – Planning and implementation of maintenance and maintenance of production equipment
F9 – Structure and functions of the management system
F10 – Degree of use of information technologies and software products in the horizontal and vertical communication in the organization
F11 – Effective communication and coordination between the units in the organization
F12 – Rational use of resources
F13 – Workforce qualification management

F14 – Employee commitment to the goals of the organization
F15 – Organizational culture
F16 – Analysis of the results of management decisions, risks, benefits and feedback
F17 – Flexibility and timely response in case of a problem
F18 – Using management methods and techniques to deal with current problems and their consequences

The classification of the key factors influencing the effective planning and management of the production capacity is based on the study of the driving force and the dependence of each of the key factors.

The factors presented above, influencing the production capacity and the calculated values of the driving force and the dependence of each of them, help to classify them into 4 main groups: independent, dependent, interdependent and driving (Fig. 1). Emphasis is placed on the performance that can be achieved within the existing constraints of system operation.

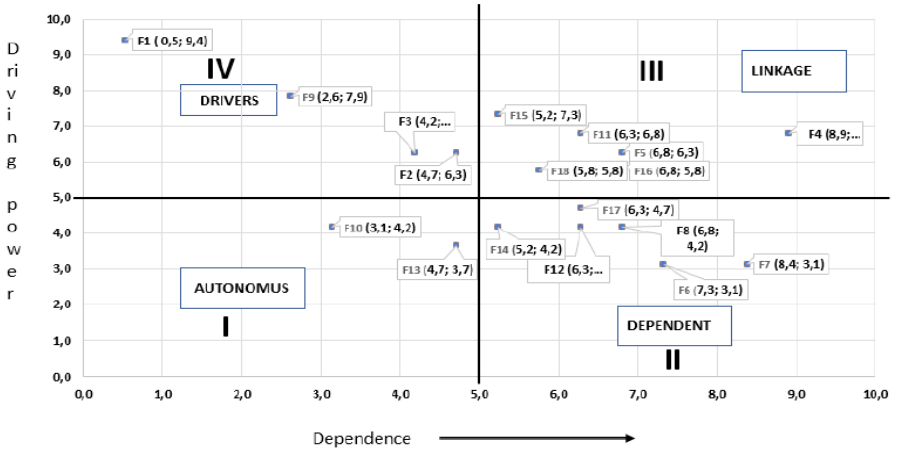

Figure 1. Diagram of the dependencies of the key factors.
Source: (Dimitrova, Panayotova, Veleva 2021)

The diagram of the dependences of the key factors divides the factors into four categories such as: independent, dependent, interdependent and driving, due to which the analysis of the factors becomes easier.

– The independent factors do not influence the other studied factors. There is no single factor that has a strong driving force as well as a strong dependence. Thus, it can be concluded that among all the 18 factors selected in this study, none is unstable. There is not a single factor that stands out with both a

weak driving force and low dependence. This proves that the surveyed factors play a crucial role in the effective management and planning of production capacity and justifies the need to examine the relationships between the factors that have been previously identified (Dimitrova, Panayotova, Veleva 2021).

– The dependency chart presents key factors such as senior management engagement, corporate and production strategy, resource planning and the structure and functions of the management system at the top left of the model, characterized by a strong driving force. It is on these driving factors that production managers need to pay special attention, because they are the main drivers for achieving effective planning and management of the production capacity of the industrial enterprise. Factors such as: mechanization and automation of production, degree of efficiency and use of production equipment, planning and implementation of prevention and maintenance of production equipment, rational use of resources, employee commitment to the goals of the organization and flexibility and timely response. These are the dependent factors that production managers need to pay close attention to. These factors are complex, and this necessitates a more careful analysis to determine and manage their significance for the manufacturing plant (Dimitrova, Panayotova, Veleva 2021).

– Defined as interdependent factors: planning and effective management of production capacity, level of production organization, effective communication and coordination between units in the organization, organizational culture, analysis of the results of management decisions, risks, benefits and feedback, and use of management methods and techniques for dealing with current problems and their consequences are unstable due to the fact that any change that has occurred in them will have an effect on others, as well as feedback for themselves. These factors are complex, which makes it necessary for the production managers to analyze and apply them more carefully and thoroughly (Dimitrova, Panayotova, Veleva 2021).

– The driving factors with a strong driving force, but weak dependence are those that have a strategic role in the organization, development and improvement of production management of the industrial enterprise (Dimitrova, Panayotova, Veleva 2021).

Developed in the present paper, through the use of ISM, is a model of the relationships and interrelationships between different key factors. The modelling of the structural equation, also known as the linear approach to structural connection, can be applied to test the validity of such a hypothetical model and is the subject of future research.

After classifying the considered key factors into 4 main groups of categories, the research proceeds to the next second stage.

Second stage

The object of analysis and research in the second stage are the factors falling into the two groups of interdependent and dependent. The aim is to explore and analyze their interrelationships in the following sequence:

1. Determining the relationships between the key factors most influencing the functioning and management of production capacity in industrial enterprises.
2. Determining the significance (priority) of the factors determined during the first stage of the research as interdependent and dependent factors.
3. Determination of the weighted overall priority of interdependent and dependent factors.

Factors have different importance and weight when making managerial decisions related to the efficient use of production capacity. Determining the relative importance of factors from the two groups begins with an assessment of their priority by applying the AHP method (Analytic Hierarchy Process). In the literature, there is almost no information about the application of the AHP method in production management, and this determined the choice of the team to accept the challenge and experiment with the application of the method for planning and effective management of production capacity (Saaty 1980; Forman, Saul 2001; Saaty, Peniwati 2008).

2. Determining the relationship and conditionality between the various factors that contribute to the construction and operation of a concept for maximum good planning and management of production facilities

The AHP method is a structured technique for organizing and analyzing complex solutions. It was developed by Thomas L. Saati in the 1970s. (Saaty 1980). It represents an accurate approach for quantifying the weight of criteria for managerial decision-making.

In the analysis of the interdependent and dependent factors affecting the decisions on the planning and use of the production capacity of industrial enterprises in order to increase its efficient and flexible use, the initial matrix is obtained from the information obtained from a survey of experts by comparing pairs of factors using a scale for determining the importance (priority) of factors in pairs from 1 to 9 (Panayotova 2004).

To obtain the required weights, all factors from the analyzed interdependent and dependent key factors are compared in pairs. The results of these pairwise comparisons form a matrix. In the AHP method, the task is reduced to a task of finding the weights of the elements (key factors) at each level with respect to each element of the higher level.

Factors are compared in pairs in terms of their importance for efficient planning and utilization of production capacity. Comparison expresses the relative importance (priority) of one factor over another.

Level 1

Determining the importance (priority) of interdependent factors (Table 2 and Table 3)

Table 1. Determining the significance (priority) of interdependent factors by pairs

Interdependent factors	F4	F5	F11	F15	F16	F18
F4	1	2	5	3	4	3
F5	1/2	1	3	2	5	4
F11	1/5	1/3	1	2	4	3
F15	1/3	1/2	1/2	1	3	4
F16	1/4	1/5	1/4	1/3	1	4
F18	1/3	1/4	1/3	1/4	1/4	1

Table 2. Determining the significance (priority) of interdependent factors by pairs – converted data

Interdependent factors	F4	F5	F11	F15	F16	F18
F4	1	2	5	3	4	3
F5	0,5000	1	3	2	5	4
F11	0,2000	0,3333	1	2	4	3
F15	0,3333	0,5000	0,5000	1	3	4
F16	0,2500	0,2000	0,2500	0,3333	1	4
F18	0,3333	0,2500	0,3333	0,2500	0,2500	1
∑	**2,6167**	**4,2833**	**10,0833**	**8,5833**	**17,2500**	**19,0000**

Level 2

Normalization of the importance (priority) of interdependent factors

By dividing the values in the individual cells of the matrix, their normalized values are obtained. These values are then averaged over the rows. The obtained average values show the relative weight (significance) of each of the factors (Table 3).

Table 3. Normalized values of the significance (priority) of the interdependent factors

Interdependent factors	F4	F5	F11	F15	F16	F18	Average
F4	0,3822	0,4669	0,4959	0,3495	0,2319	0,1579	0,3474
F5	0,1911	0,2335	0,2975	0,2330	0,2899	0,2105	0,2426
F11	0,0764	0,0778	0,0992	0,2330	0,2319	0,1579	0,1460
F15	0,1274	0,1167	0,0496	0,1165	0,1739	0,2105	0,1324

F16	0,0955	0,0467	0,0248	0,0388	0,0580	0,2105	0,0791
F18	0,1274	0,0584	0,0331	0,0291	0,0145	0,0526	0,0525
∑	**1,0000**	**1,0000**	**1,0000**	**1,0000**	**1,0000**	**1,0000**	**1,0000**

The analysis shows that according to the normalized values of significance (priority), the interdependent factors that are most important in the effective planning of production capacity are arranged as follows:

1. Planning and effective management of production capacity (F4).
2. The level of organization of production (F5),
3. Effective communication and coordination between units in the organization (F11)
4. Organizational culture (15)
5. Use of management methods and techniques to deal with current problems and their consequences (F16)
6. Using management methods and techniques to deal with current problems and their consequences (F18).

Level 3

In order to determine the reliability of the obtained results, it is necessary to make additional calculations.

The total weight is expressed by expressing the overall priority of the factors by multiplying the matrix of comparative values by pairs of factors by their average normalized weight.

In order to determine the reliability of the obtained results it is necessary to make additional calculations. First, the so-called "total weight" is determined, which expresses the overall priority of the criteria (factors) by multiplying the matrix of comparative values by pairs of factors by their average normalized weight. This is shown in Figure 2

Interdependent factors	F4	F5	F11	F15	F16	F18		Average
F4	1	2	5	3	4	3		0,3474
F5	0,5000	1	3	2	5	4		0,2426
F11	0,2000	0,3333	1	2	4	3	X	0,1460
F15	0,3333	0,5000	0,5000	1	3	4		0,1324
F16	0,2500	0,2000	0,2500	0,3333	1	4		0,0791
F18	0,3333	0,2500	0,3333	0,2500	0,2500	1		0,0525

Figure 2. Determining the "total weight" of interdependent factors

Table 4 presents the "weighted overall priority" of the interdependent factors.

Table 4. Determining the weighted overall priority of the interdependent factors

Total weight	Average	Weighted overall priority
2,4338	0,3474	7,0063
1,7246	0,2426	7,1095
1,0350	0,1460	7,0875
0,8898	0,1324	6,7181
0,5051	0,0791	6,3890
0,2469	0,0525	4,7023
∑		**39,0127**

Verification of the reliability of the obtained results

The levels of relative importance determined by the experts participating in the study should be checked for reliability.

The degree of reliability of the significance of the compared indicators is determined as follows (1) The degree of reliability of the significance of the compared factors is determined by the reliability indicator CR.

$$CR = \frac{CI}{RI} \quad (1)$$

Where:

CI is the reliability index;

RI – random variable; is determined depending on the number of compared objects n of the Table 5:

Table 5. Determining the value of the random variable RI depending on the number of compared objects (n)

n	2	3	4	5	6	7	8	9	10
RI	0,00	0,58	0,90	1,12	1,24	1,32	1,41	1,45	1,51

Source: *(Stevenson J., Ozgur C, 2007)*

The reliability index is determined using formula (2):

$$CI = \frac{\lambda a - n}{n-1} \quad (2)$$

Where

λa – the weighted average overall priority;

Comparisons are considered valid when CR <0.10 (Hanfield, Walton, Sroufe, Melnyk, 2002).

Specific for the study:

Table 6. Determining the relative importance of interdependent factors

Weighted average overall priority λ	6,5021	
CI	0,1004	
RI	1,24	
CR = CI/RI	**0,0810**	**< 0,10**

Therefore, the results for the relative importance of the factors from the group of interdependent factors can be considered reliable.

Dependent factors

Level 1

In a similar way, the analysis of the dependent factors was performed by applying the AHP method.

The determination of the importance (priority) of the dependent factors is presented with the help of Table 7 and Table 8.

Table 7. Determining the significance (priority) of dependent factors by pairs

Dependent factors	F6	F7	F8	F12	F14	F17
F6	1	2	3	2	3	4
F7	1/2	1	3	4	3	2
F8	1/3	1/3	1	3	3	4
F12	1/2	1/4	1/3	1	3	3
F14	1/3	1/3	1/3	1/3	1	4
F17	1/4	1/2	1/4	1/3	1/4	1
∑	**2,9167**	**4,4167**	**7,9167**	**10,6667**	**13,2500**	**18,0000**

Table 8. Determining the significance (priority) of dependent factors by pairs – converted data

Dependent factors	F6	F7	F8	F12	F14	F17
F6	1	2	3	2	3	4
F7	0,5000	1	3	4	3	2
F8	0,3333	0,3333	1	3	3	4

F12	0,5000	0,2500	0,3333	1	3	3
F14	0,3333	0,3333	0,3333	0,3333	1	4
F17	0,2500	0,5000	0,2500	0,3333	0,2500	1
∑	**2,9167**	**4,4167**	**7,9167**	**10,6667**	**13,2500**	**18,0000**

By dividing the values in the individual cells of the matrix, their normalized values are obtained. These values are then averaged over the rows. The obtained average values show the relative weight (significance) of each of the factors (Table 9).

Table 9. Normalized values of the significance (priority) of the dependent factors

Dependent factors	F6	F7	F8	F12	F14	F17	Average
F6	0,3429	0,4528	0,3789	0,1875	0,2264	0,2222	0,3018
F7	0,1714	0,2264	0,3789	0,3750	0,2264	0,1111	0,2482
F8	0,1143	0,0755	0,1263	0,2813	0,2264	0,2222	0,1743
F12	0,1714	0,0566	0,0421	0,0938	0,2264	0,1667	0,1262
F14	0,1143	0,0755	0,0421	0,0313	0,0755	0,2222	0,0935
F17	0,0857	0,1132	0,0316	0,0313	0,0189	0,0556	0,0560
∑	**1,0000**	**1,0000**	**1,0000**	**1,0000**	**1,0000**	**1,0000**	**1,0000**

It is noteworthy that the weights of the dependent factors are relatively close and with little difference between them. The highest value obtained for Mechanization and Automation of Production (F6) is 0.3018, and the lowest value – 0.0560 receives Flexibility and timely response in case of a problem (F17).

In order to determine the reliability of the obtained results, it is necessary to make additional calculations.

The total weight is expressed by expressing the overall priority of the factors by multiplying the matrix of comparative values by pairs of factors by their average normalized weight.

In order to determine the reliability of the obtained results it is necessary to make additional calculations. First, the so-called "total weight" is determined, which expresses the overall priority of the criteria (factors) by multiplying the matrix of comparative values by pairs of criteria (factors) by their average normalized weight. This is shown in Figure 3.

Dependent factors	F6	F7	F8	F12	F14	F17		Average
F6	1	2	3	2	3	4		0,3018
F7	0,5000	1	3	4	3	2		0,2482
F8	0,3333	0,3333	1	3	3	4	X	0,1743
F12	0,5000	0,2500	0,3333	1	3	3		0,1262
F14	0,3333	0,3333	0,3333	0,3333	1	4		0,0935
F17	0,2500	0,5000	0,2500	0,3333	0,2500	1		0,0560

Figure 3. Determining the "total weight" of dependent factors

Table 10 presents the definition of the "weighted overall priority" of the inter-dependent factors.

Table 10. Determining the weighted overall priority of the dependent factors

Total weight	Average	Weighted overall priority
2,0781	0,3018	6,8857
1,8192	0,2482	7,3290
1,2407	0,1743	7,1169
0,8457	0,1262	6,7034
0,6011	0,0935	6,4309
0,2820	0,0560	5,0322
∑		39,4982

Verification of the reliability of the obtained results
Specific for the study:

Table 11. Determining the relative importance of dependent factors

Weighted average overall priority	6,5830	
CI	0,1166	
RI	1,24	
CR = CI/RI	0,0940	< 0,10

Therefore, the results for the relative importance of the factors from the group of dependent factors are reliable.

3. Conclusion

Production capacity is a key complex economic parameter of the enterprise and its effective planning and management is the basis of success and competitiveness of any production organization.

Therefore, for the planning and effective management of production capacity, it is necessary to study and analyze the relationships between the key factors influencing production capacity, their importance and priority.

In the presented study by applying the method AHP (Analytical hierarchical process), the interdependent and dependent factors identified in a previous study that affect the production capacity of enterprises are analyzed.

In this way, an attempt was made to contribute to the construction and operation of a concept for maximum good planning and management of production facilities of industrial enterprises.

In the present study, a generalized research model of the key factors influencing the effective planning and use of production facilities in the industrial enterprise is presented, for which a software product can be developed. The model is suitable for developing a software product according to the proposed algorithm, with the help of which management decisions related to production capacity can be made quickly and adequately.

Work on expanding the scope of scientific research continues. The positive results achieved give reason to deploy it to a wider scale in search of effective practical application in different types and sizes of production enterprises.

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