Methodology of Quantitative and Qualitative Evaluation of an Industrial Enterprise Digital Potential on the Example of Evaluation of the "Personnel Resources" Component

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Abstract. The purpose of the paper is to offer a method of quantitative estimation of the industrial enterprises digital potential and qualitative analysis of its components as the factor of development of industrial structure. Introduction of the enterprise digital potential concept and development of a method to quantify its components will allow to carry out the analysis and to reveal ways of improvement of interrelations between structural divisions, to increase flexibility and adaptability of industrial structure. For this purpose, the existing concepts of digital potential have been considered, the author's definition has been offered, the main components of digital potential have been singled out, the single indicators of evaluation of the «Personnel resources» component have been defined and the distance method for calculation of the integral indicator of the «Personnel resources» as one of the components of the digital potential has been chosen. The authors also showed the possibility of using cognitive models for qualitative analysis of the components of digital potential and their impact on the level of digitalization of the enterprise. For this purpose, the main factors influencing the development of digital potential, the structure and strength of relationships were identified, and a cognitive model was developed. Cognitive model of the digitalization of the industrial enterprise has shown the strength of the impact of factors related to human resources on the overall digital level of the enterprise. Theoretical and practical significance of the obtained result lies in the formation of methodical apparatus to assess the readiness of personnel for digital transformation of industrial enterprise, providing the development of production structure.

1. Introduction
The modern industrial enterprise represents set of the divisions various on the kind of activity, connected among themselves by uniform process of manufacturing of production. Today one enterprise can provide full life cycle of a product, including an interrogation, industrial and post-production stage [1-3]. Inside one enterprise the research and development works, market research, product manufacturing, sales are carried out. It leads to increase in quantity, expansion of structure of divisions, complication of their interrelations. Consequently, new requirements are put forward for the design of a production structure (PS) that ensures close production links between the workshops, sites, workplaces and control points which are implemented digitally in the information space.

Digitalization of the industrial enterprise is a factor responsible for the level of development of the PS. Stability of production relations which influence rhythmicity of manufacture and uniformity of output, and also on adaptability and flexibility of manufacture as a whole, i.e. ability to operative
reconstruction of all organization depends on structure developed on manufacture. The concept of
digitalization here implies the digital potential of an industrial enterprise. Today there are difficulties
and inconsistencies in definitions and calculations of the digital potential (DP) of industrial enterprises
between different scientists [4,5].

The most common approach is to define DP as a characteristic of the capacity of economic systems
to use digital technology. It is used to describe the situation with the use of digital technologies in
regional markets [5], territories [6,7,8] or industries [9; 10]. As applied to an enterprise, the concept of
DP in the first sense is used to describe the possibility of building a more efficient information
management system by expanding the use of computer programs, improving information literacy of
personnel [11] or introducing digital technologies in the production process [12].

Thus, the DP is considered as a set of data itself, software and hardware for their storage and
processing, and personnel using the data for enterprise management [13]. Also, DP is defined as the
ability of an enterprise to carry out activities to create, implement and use information technology (IT)
and to provide information security in order to meet current or future needs of both the enterprise and
its stakeholders [14]. That is, most authors link the concept of DP with the use of information
technologies and corresponding software. However, this approach ignores the purpose of introducing
technologies and software. The final result is not only the conversion of all processes into electronic
form and the use of all possible information tools to create a digital twin enterprise. The main objective
should be to ensure the production of high-tech competitive products in the shortest possible time due
to the flexibility and speed of production processes that depend on the level of PS development. The
level of PS development, in its turn, is provided by application of advanced technologies, availability
of modern equipment, qualification of personnel, application of modern management methods taking into
account principles of resource saving and ecological compatibility. Thus, the DP of an enterprise is not
only its ability to apply IT; it is the ability to use these IT with the greatest efficiency in production
processes, which directly depends on the type of production technologies used, the available production
facilities and personnel working on the factory equipment. In this regard, the authors propose the
following definition: the digital potential of an industrial enterprise is a set of technical and
 technological, information and human resources, forming a developed production structure that provides
a sustainable production of high-tech competitive products in dynamic environmental conditions.

2. Methods

Various mathematical methods can be used for complex numerical evaluation of DP, among them various
methods of deterministic complex evaluation, which are widely used, in particular, in the analysis of
economic activity of enterprises. The authors suggest using the distance method. When using the distance
method, the closeness of an enterprise or a structural unit to an object-standard is established for each of
the compared indicators. A conditional object with maximum values for stimulator indicators and
minimum values for demo- indicators can be taken as an object- standard. [15]. According to the method,
the coefficients for each indicator are first defined as the ratio of its value to the value of the benchmark
(for example, with a maximum value). Then the sum of squares of deviation of the coefficients from the
one is calculated. If it is possible to determine the importance of the single indicators in the system, the
corresponding weighting coefficients \( k_i \) are used.

\[
R = \sum_{i=1}^{n} k_i \left(1 - \frac{x_{ij}}{x_{i,m+1}}\right), j = 1, m,
\]

where \( x_{i,m+1} \) is the reference value of the \( i \)-th indicator; \( x_{ij} \) – \( i \)-th index value for the \( j \)-th component;
Criterion for evaluation of high DP is minimum value of \( R \).

The authors use cognitive modeling technology for qualitative analysis of DP components. The
Method is based on an expert view of a system, including the construction of the sign-oriented graph
and the calculation of factors changes in the dynamics by using management actions. A sign-oriented graph is a cognitive map consisting of factors and cause-and-effect relationships between them.

\[ G = \langle V, E \rangle \]  

Where: V is a vertex of the graph, the system factors; E is the set of arcs describing the relationship between vertices. The cognitive model is represented by a vector functional graph:

\[ F = \langle G, X, F \rangle \Phi \]  

Where: X is the set of parameters of the vertex V; F=F(X,E) is a functional transformation of arcs, which puts in conformity to each arc, a weight coefficient wij denotes the strength of the interaction.

If it is not possible to represent factors quantitatively, linguistic values of estimation of force of communication are chosen. They can be set using the digits corresponding to the interval \([0;1]\). The scale describing the power of influence is presented in Table 1.

| Weigh | Interpretation of the influence power |
|-------|-------------------------------------|
| 0     | No influence                         |
| 0,1   | Virtually absent                     |
| 0,3   | Weak                                |
| 0,5   | Average                             |
| 0,7   | Significant                         |
| 0,9   | Strong                              |
| 1     | Maximum possible                    |
| 0,2; 0,4; 0,6; 0,8 | Intermediate levels |

Table 1. Scale of interpretation of the influence power.

Interaction of factors is based on perturbation (impulse) and its transmission. The increment of the factor value \( p_i(0) = x_i(1) - x_i(0) \) is the initial pulse. The components of the vector \( P(t+1) \) are computed:

\[ p_i(t + 1) = \sum_j w_j \cdot p_j(t) \]  

In this method, the initial values of all factors can be considered zero, then the predictive vector of factor values is determined by the accumulated increment of factor values for n steps of the model:

\[ x_j(n) = \sum_{t=0}^{n} p_j(t) \]  

3. Results

For quantitative evaluation of DP it is necessary to highlight its components: the main components. (see Fig.1.)

As an example of evaluation of the DP of an industrial enterprise, we propose to consider the evaluation of the "Personnel resource" component. In this block the number of employees of the enterprise, level of education, profile of education, qualification, competence, including digital, level of adaptation to changes connected with digital transformation and age should be estimated.

The human resources component is defined by a set of single indicators. The first indicator is the indicator of digitalization of labor. Digital production is a desolate production. Due to Oxford Economics Analytics Robots will replace up to 20 million factory jobs by 2030 [16]. The advantage is that unmanned production can work without shifts, the human factor is excluded, productivity and accuracy increases, the efficiency of machines does not depend on working conditions and harmful factors.

\[ x_1 = I_{DL} = 1 \]  

with a 30% reduction in production workers in 5 years and \( x_1 = I_{DL} = 0 \) with a reduction in production workers of less than 7% in 5 years.
Most employees in smart plants will face the need to use digital tools [17-18]. The percentage of employees involved in working with digital technologies and equipment is estimated by the indicator of employees' use of digital resources:

\[ x_2 = \frac{I_{UDT}}{P_{DT}} = \frac{P_{DT}}{P} \]  

(7)

Where \( P_{DT} \) is the total number of company personnel involved in the use of digital resources; \( P \) - the average number of employees of the enterprise.

In order for staff to be able and effectively carry out their work digitally, they need education and ongoing retraining and development [19].

Indicator of personnel education:

\[ x_3 = \frac{I_{PE}}{P_{HE}} = \frac{P_{HE}}{P} \]  

(8)

Where \( P_{HE} \) is the number of employees with higher education.

Personnel training indicator:

\[ x_4 = \frac{I_{PT}}{P_{DE}} = \frac{P_{DE}}{P} \]  

(9)

Where \( P_{DE} \) is the number of employees who have been digitally educated and retrained.

In case of lack of internal human resources, it is possible to attract external staff with digital competences. Indicator of attraction of external personnel:

\[ x_5 = \frac{I_{EP}}{P_{AD}/P_{D}} = \frac{P_{AD}}{P_{D}} \]  

(10)

\( P_{AD} \) - number of attracted personnel with digital competences. \( P_{D} \) - number of personnel with digital competences.

Digital technology can be effective not only in design or production [20]. Augmented and virtual reality technologies can be used to accelerate and improve employee learning. The learning virtualization indicator is calculated as follows:

\[ x_6 = \frac{I_{LV}}{P_{VL}} = \frac{P_{VL}}{P} \]  

(11)

Where \( P_{VL} \) is number of employees trained with the help of augmented and virtual reality technologies.

Personnel play a key role in the digital transformation of an enterprise. In order to overcome resistance to innovation and to adapt to new tools, instruments, processes, information about the benefits of digital transformation should be publicly available, moreover, employees need to participate in motivational seminars and briefings. The indicator of personnel adaptation to the digital environment is calculated as follows:

\[ x_7 = \frac{I_{PA}}{P_{A}} = \frac{P_{A}}{P} \]  

(12)

Where, \( P_{A} \) is a number of employees who have been adapted to the digital environment.
Based on the results of Superjob.ru research center, the ideal age of an employee is 24-36 years. From 36 to 50 years of age the achieved results are maintained, and after 50 years of age the ability to work is significantly reduced. Therefore, the next indicator of the age of employees:

\[ x_8 = \frac{I_{P_{0\alpha}}}{P} \]

Where \( P_{0\alpha} \) is number of specialists over 50 years of age.

After calculating the single indicators, it is necessary to apply the distance method mentioned in section Methods.

However, in the current economic conditions, industrial enterprises do not pay sufficient attention to aspects related to human resources. More attention is paid to the choice of digital technologies, provision of technological base, level of investments, requirements to product quality. But it can be clearly demonstrated how the level of digitalization of an enterprise depends on human resources. Let us carry out cognitive modeling on the example of the Russian enterprise «Autodiesel». The products of the enterprise are multi-purpose diesel engines, clutches, gearboxes, spare parts and stationary units based on them.

So, firstly we need to highlight the main technical, technological and socio-economic factors of the digitalization of production, and then determine the level of interconnection between them. The interrelation matrix presents the main factors as well as qualitative and quantitative relations between them (see Table 2). The strength of relationships is revealed by direct assessment: how a change in one factor will affect the change in another. Direct assessment is used if changes can be clearly measured, or if there are many possible factor values and subjective probability of each value [21].

Table 2. Relationship matrix.

|          | A  | B  | C  | D  | E  | F  | G  | H  | I  | J  | K  |
|----------|----|----|----|----|----|----|----|----|----|----|----|
| Level of digitalization of production (A) | 0  | 0,7| 0,8| 0,8| 0  | 0  | 0  | 0  | 0  | 0  | 0  |
| Implementation period (B)                 | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |
| Level of investment (C)                   | 0  | 0  | 0  | 0  | 0  | 0,6| 0  | 0  | 0  | 0  | 0  |
| Level of personnel qualification (D)     | 0  | 0  | 0  | 0  | 0  | 0  | 0,8| 0  | 0,6| 0  | 0  |
| Product quality (E)                       | 0,7| 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |
| Customer demand (F)                       | 0  | 0  | 0  | 0  | 0,6| 0  | 0  | 0  | 0  | 0  | 0  |
| Quality of education (G)                  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0,7| 0  | 0  | 0  |
| Skills development (H)                    | 0  | 0  | 0,6| 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |
| Level of adaptation (I)                   | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |
| Age (J)                                  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0,2| 0,8| 0  |
| Job cuts (K)                              | 0,5| 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |

The matrix can be read as follows: with a 10% increase in the level of digitalization of the enterprise, product quality will increase by 7%, and jobs will be reduced by 5%. Or, if customer demand grows by
10%, investment will increase by 6%. On the basis of the interrelation matrix we will make a cognitive model of the level of digitalization of the industrial enterprise (see Fig.2).

Now with the help of cognitive model we will substantiate the importance of factors related to human resources of the enterprise.

Let's select factors that are subject to management influence. The management of the enterprise by means of certain measures is able to influence the level of adaptation of employees to new conditions. If the level of adaptation increases by 10%, the cognitive model shows an increase in the level of digitalization of the enterprise by 8.3% to the conditional fourteenth period.

With an increase of the "Skills development" factor, the digitalization level of the enterprise will increase by 7.7%. And if a manager is able to increase "Skills development" and "Level of adaptation" simultaneously by 10%, the level of digitalization of the enterprise will increase by 16.5% (see Fig.3).

Please note that with the increase in adaptation and skills development, the level of digitalization of the enterprise increases in the second step and the time of technology implementation decreases, in the third step the quality of products increases, and then the demand increases in the fourth step. However, with the constant development of digital potential, we see a decline in adaptation and a gradual decrease in skills, which indicates a constant need to maintain these parameters at the level. Therefore, the cognitive model of digital production development allows to identify in advance the necessary values of the level of qualification of personnel, adaptation and other parameters and determine the strategy of their maintenance for the transition of production processes to the digital level.

Figure 2. Cognitive model of production digitization.
4. Results
Thus, such parameters as introduction of digital and information technologies at the enterprise, use of computer programs and increase of information literacy of the personnel cannot be considered under the DP separately. Therefore, the authors cite the concept and methodology of evaluation of the DP of the industrial enterprise, identifying four main components of the DP, the coordinated interaction of which will ensure both stability, flexibility and development of the production structure of the enterprise. In order to assess the current level of the enterprise's DP, it is necessary to quantify all the components and calculate a summary index. In this paper, the authors proposed the main indicators for calculating the "personnel resource" component. In view of the lack of due attention to this aspect from the management of industry, the authors have clearly demonstrated through cognitive modelling methodology how age, adaptation, obtaining and development of digital skills affect the level of digitalization of the enterprise. The practical contribution of the work is that, thanks to quantitative and qualitative analysis, enterprises will not only be able to determine their current level of DP in terms of human resources, but also to define a strategy for its development.

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