ASSESSING BULGARIAN SMEs' MATURITY FOR INDUSTRY 4.0 IMPLEMENTING – THE CASE OF "MONTANA HYDRAULICS" LTD

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Abstract
This publication presents the application of developed in Peneva (2021) "Model for Assessing Bulgarian SMEs' Readiness for Industry 4.0" in a Bulgarian SME: "Montana Hydraulics" Ltd. In the model, the approach of the series of international standard ISO/IEC 33000 "Information Technology - Process Assessment" is used and adapted. For this purpose, the current state of the SME was analyzed and its maturity was assessed according to 5 Industry 4.0 priority areas selected together with the company's management. Based on the research, measures are proposed to reach the target maturity and recommendations for investment priorities about these 5 target areas are made.

Keywords: *Industry 4.0, Maturity Models, SMEs, Readiness for I4.0, ISO/IEC Standards*

1. Introduction

Small and medium-sized enterprises (SMEs) are the driving force of many national economies (European Commission, 2018b). They often face much more different challenges and barriers than large companies and multinationals (Wuest & Thoben, 2011; Wadhwa, 2012). A 2017 survey conducted among manufacturing SMEs in West Virginia, USA, confirms their willingness and the tendency of these SMEs to implement Smart Manufacturing (SM) (Wuest at al., 2018). An in-depth review of the literature on the subject shows that very few studies have focused specifically on supporting SMEs in their transition to Industry 4.0. Some authors (Nagy, 2017; European Commission, 2018a) even call successful SMEs in this direction "SMEs 4.0". Modern production is complex. Various studies have been presented in the literature (Esmaeilian, at al., 2016) focusing on how SMEs deal with, and in many cases, "fight" this complexity. Müller & Voigst (2017) analyzed Industry 4.0 implementation strategies in German SMEs and interviewed 68 experts, including 41 CEOs in companies engaged in (1) mechanical engineering and manufacturing, (2) electrical engineering and (3) automotive suppliers. They conclude that standardization, staff capacity, financial resources and trust in digital services are serious constraints for SMEs. Many German SMEs have not yet moved to the new paradigm of Industry 4.0 (Rickman, 2018; Sommer, 2015), and many of them also ignore the related digitalization trends and automation (Sommer, 2015; Knop, 2018). For its part, Nieuwenhuize (2016) analyzed six Dutch SMEs from different manufacturing sectors in order to investigate their strategic orientation for moving to Industry 4.0. Based on their intention and receptivity to Industry 4.0 technologies and practices, the author classified the studied SMEs into three segments: (1) latent, (2) "captives" and (3) implementers.

SMEs often lack research resources and search for new paradigms outside of their core competencies. However, they must quickly learn emerging technologies and digital practices to compete with large enterprises (Faller & Feldmüller, 2015) that have already begun their transformation to Industry 4.0. Veza et al. (2015) used a survey among 159 companies, of which 69% were SMEs. According to the results, the level of maturity of Croatian enterprises is such that they have not yet started to apply Industry 4.0 technologies, but are still in the era of the Second Industrial Revolution.

In Rauch et al. (2020) an extremely comprehensive review is presented in the leading and one of the most complete scientific databases – SCOPUS of the trends/concepts/technologies involved in Industry 4.0. The authors identify 42 concepts and technologies as elements of Industry 4.0, grouped into 4 directions (Organization, Technology, Operations, Socio-Culture). This classification, in turn, served as the basis for the developed in Peneva (2021) *Model for assessing the organizational maturity of Bulgarian SMEs for the implementation of Industry 4.0*. The present publication presents the application of the model in a medium-sized Bulgarian machine building enterprise.

2. Essence of the Model for Assessing the Organizational Maturity of Bulgarian SMEs for Implementing Industry 4.0

Despite the existence of many and different approaches to the development of organizational maturity assessment models, it should be noted that over the last two decades the approach laid down in the series of international standards ISO/IEC 15504, subsequently replaced in 2015 by the ISO/IEC 33000 "Information Technology – Process Assessment" series developed for the ICT sector (Rauch, at al., 2020; Amaral, at al., 2019; Vrchota at al., 2019, etc.).

2.1. Basics

According to the approach adopted in ISO/IEC 33000, the procedure is as follows:

- A **Process Assessment Model** (PAM) is developed, which is based on an appropriate reference source of process definitions based on one or more **Process Reference Models** (PRM);
- PRM is to be integrated with the so-called **Process Measurement Framework** (PMF);
- The requirements that a PAM must meet to be compliant in its interactions with specific PRMs are defined in Clause 6 of ISO/IEC 33004:2015;
- **The Maturity Model** (MM) can be constructed using different PAMs. The requirements for MM are defined in Clause 17 of ISO/IEC 33004:2015.

It is necessary to emphasize that not all SMEs need the maximum level of maturity in relation to Industry 4.0 for their purposes, i.e. the maximum level of maturity in all directions should **not** be seen as something that must be achieved at all costs.

2.2. Defining the directions for analysis and assessment of the maturity of SMEs

In the model presented by Peneva (2021), the definition of the directions for evaluation, with the help of which to reach the determination of the level of readiness/maturity for implementing Industry 4.0, the second direction from Rauch et al. (2020) – "Technology", was decomposed into two sub-groups: (a) "Process Technologies" and (b) "ICT" (Fig. 1).

The Maturity Levels, respectively Process Capabilities, according to the ISO/IEC 33000 series are six: (0) Incomplete Process, (1) Performed Process, (2) Managed Process, (3) Established Process, (4) Predictable Process and (5) Innovative Process.

The relevant *Process Attributes* speak for reaching each particular level, and their achievement, in turn, is determined by the presence of the corresponding *Generic Practices* (ISO/IEC 33002:2015; ISO/IEC 33020:2019).

2.3. Procedure of the Maturity Assessment Model for SMEs

Schematically, working with the model is shown in Fig. 2. Management initially decides on the applicability of the relevant Industry 4.0 areas/technologies (Fig. 1) in its business and markets, and which ones the enterprise might decide to invest in. Next is the "sieving" of those among them that are most important and have the greatest effect for the specific SME – the **target directions** in which it should start working for Industry 4.0 implementing. The main role here is for managers who know the product mix and processes in the enterprise. As a next step, it is important to determine their priority and the effect of their implementation.

Фиг. 1. Групиране на основните концепции и направления на Industry 4.0 – по (Rauch at al., 2020)

For this purpose, the Analytical Hierarchy Process/AHP (Saaty, 1980) is proposed in Peneva (2021). Thanks to it, the enterprise produces a ranking by importance and economic effect of positions in the selected short list. This is followed by an analysis & assessment of the existing readiness/maturity of the enterprise in each of the target directions. Here, the adapted model for maturity assessment according to ISO/IEC 33000 mentioned in above point 2.2 is used. According to the conclusions of this analysis, a decision is made what the values should be for the relevant directions and, after conducting a GAP-analysis for the differences between the existing and the target state, a decision is made on which of the selected directions to start work first. The latter is done using the so-called Norm Strategy Matrix (Rauch at al., 2020).

3. Applying the Model for assessing organizational maturity in Montana Hydraulics Ltd. The company was established in 2006 as an enterprise producing components for hydraulic cylinders. The capital is currently owned by two Spanish companies: "GLUAL Group" and "GLUAL Hydraulics" https://www.glual.com/en/contacto.html. Originally Montana Hydraulics Ltd. acts as a subcontractor for the machining of steel components for spare parts, but later expands to the production of hydraulic cylinders as end products. According to the qualification of the European Commission, Montana Hydraulics Ltd. is a medium-sized enterprise.

3.1. Product Analysis

For the subject of the present applied experimentation, the product *Hydraulic Cylinder Double Acting KS-40/22X150* was chosen as the most suitable (Fig. 3).

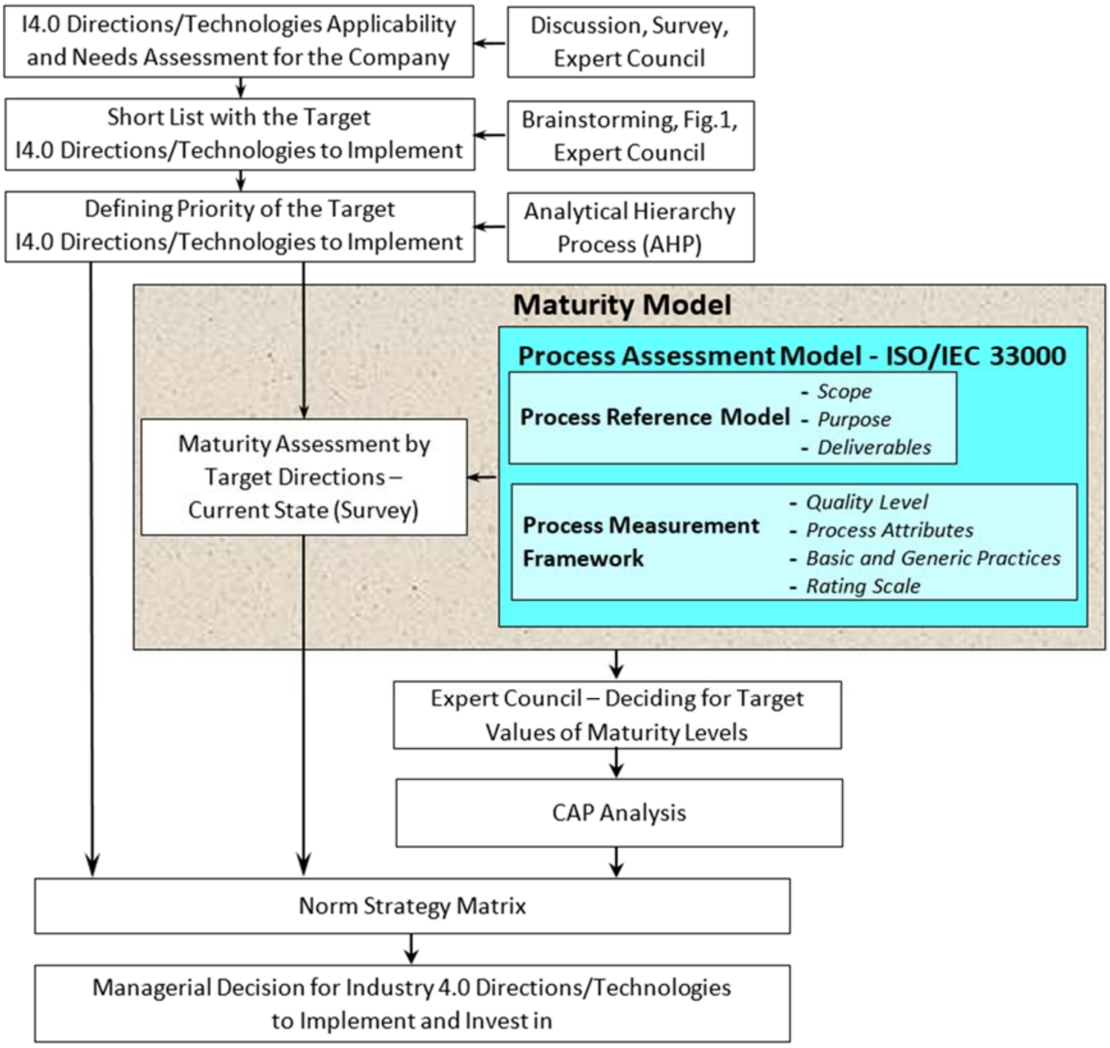


Figure 2. Block diagram of the SMEs Maturity Assessment Model (Peneva, 2021)

The main considerations for this choice are:

- The product is suitable, as it has no big structural and technological complexity, so it can easily demonstrate how the Model works in relation to manufacturing processes;
- The selected type of hydraulic cylinder has the largest share in the company's production program and therefore the it can serve as a representative product for the purposes of the study.

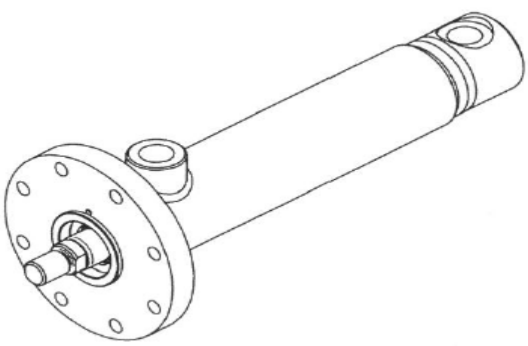


Figure 3. Axonometric view of the product

4.1. Survey on the company management awareness of Industry 4.0

According to Phase 1 of the methodology (Peneva, 2021), a survey was conducted in the enterprise regarding the knowledge and understanding of the Industry 4.0 nature, its conceptual bases and elements, their opportunities and threats for Montana Hydraulics Ltd.

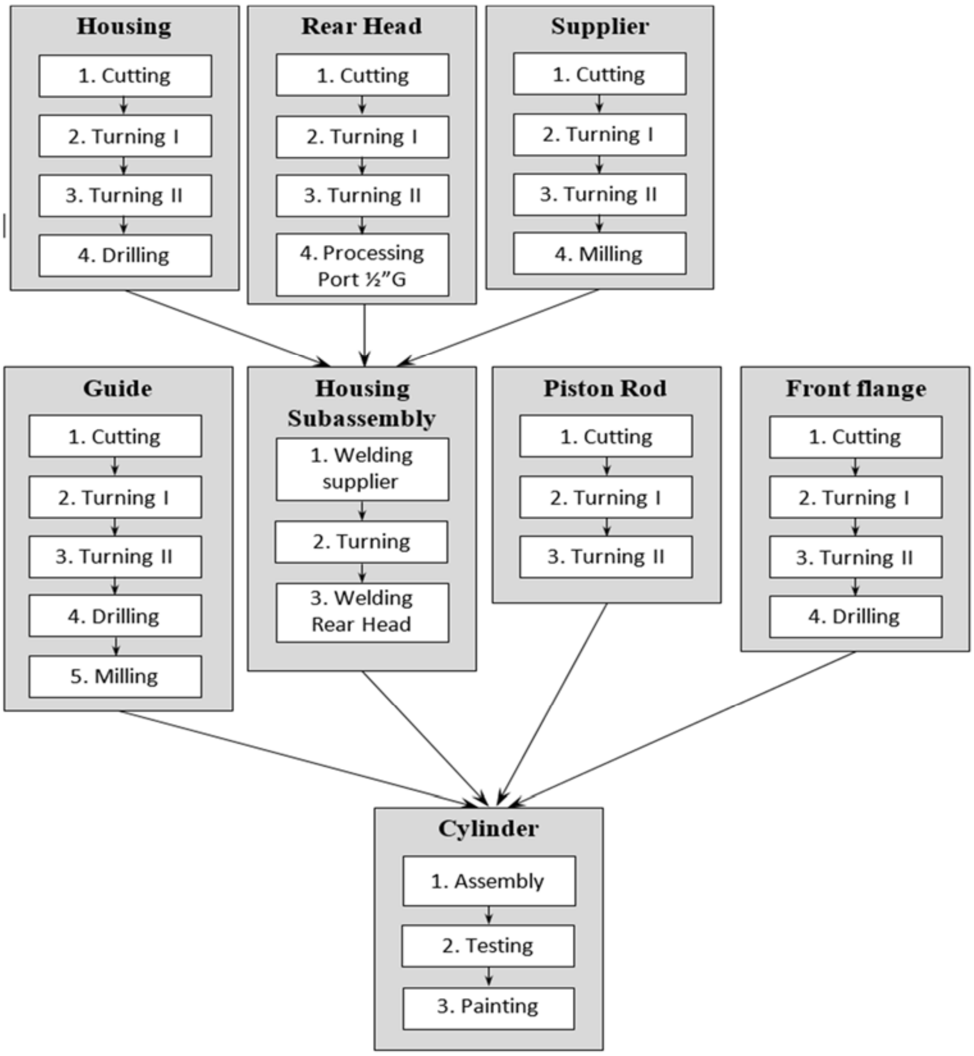
Results of the Survey

- The responsible factors in Montana Hydraulics Ltd. are aware of the nature and competitive advantages that the implementation of Industry 4.0 leads to;
- Since the senior management of the parent company "GLUAL Group" makes the strategic decisions for the group of enterprises, the management in the Bulgarian enterprise to a large extent cannot determine the policy of the enterprise in strategic areas such as Industry 4.0. However, this does not mean that the Spanish managers are not working in this direction – in the vision for the development of the enterprise group, one of the most important priorities is the implementation of Industry 4.0;
- Currently at Montana Hydraulics Ltd. there are not many implemented information technologies from the Industry 4.0 generation. In some cases, the so-called M2M communications are used;
- In general, the vision is to emphasize digitization in the enterprise in the near future;
- The implemented ERP and PDM systems are currently being used in full capacity as part of the common integrated management information system with the parent company;
- The built CAD-CAM system, which, together with ERP, is part of the Production Planning System (PPM) takes an active part in the production conditions;
- Cloud services are used within the group of enterprises – in the field of operational activity and for data storage;
- Still, at least in Montana Hydraulics Ltd., the big data analysis tool is not implemented, but this is also a strategic decision of the parent company;
- A cyber security system has been implemented in relation to cloud services, internal data exchange, communication with business partners and suppliers;
- With regard to the "Smart products" direction (which is again a consequence of the strategic vision of "GLUAL Group"), for now, the possibilities to collect information are used only for the objects where the company's products are installed and for the performance (quality) of the products themselves – the hydraulic cylinders;
- Montana Hydraulics Ltd. is not integrated with the end clients (consumers) and does not offer information about its processes due to the fact that it is a subcontractor of "GLUAL Hydraulics". In fact, if we consider "GLUAL Hydraulics" as a client of Montana Hydraulics Ltd., one can already argue for almost complete such integration.
- Regarding employees' knowledge and skills about Industry 4.0, Montana Hydraulics Ltd. can boast of a good potential for implementation in this direction. The company's employees are "on the level" and have adequate knowledge and skills in IT, automation, data and communications security, collaboration software, systems thinking and process understanding.

4.2. Process Assessment Model (PAM)

A PAM was elaborated, and for this purpose a Process Reference Model (PRM) was first developed. The PRM refers to the manufacture of the product *"Hydraulic Double-Acting Cylinder KS-40/22X150-A03-F-M-00".* The processes, the subject of the present reference model, concern the technology for the manufacture of the specified product - the technological maps for the manufacture of the relevant components and those for assembly have been examined that of the assemblies/ final product. The reference model consists of the successive operations that must be carried out in order to produce the final product. The description of the interaction between the processes in the PRM is depicted in the block diagram of Fig. 4.

The **purpose** of the process is the production of high-quality hydraulic cylinders (the **result**), with technical and operational indicators, corresponding to the parameters required by customers and described in the company's catalog (www.glual.com/en/productos/cilindros_hidraulicos.html).



Фиг. 4. Manufacturing process flowchart for End Item: Cylinder KS-40/22X150-A03-F-M-00

The distinct technological operations are described in operations maps – route and operational ones, where the quality characteristics of the product and the process are indicated, which need to be tracked in order to guarantee the receipt of the result appointed. In relation to the quality compliance, the company has implemented a Quality Management System according to ISO 9001:2015. All activities in the design, implementation, production and management of the processes in the enterprise are in accordance with the requirements of the international standard. Audits are regularly conducted by the internationally authorized institutions for the purpose.

According to Peneva (2021), the Process Measurement Framework presented in the ISO/IEC 33020:2019 is used step by step. It represents the indicators with the help of which the specified level of quality of the process and the process capabilities of the enterprise is reached through the Process Attributes reached. These indicators – "Practices" (basic and generic), information, available resources and infrastructure of the enterprise, are included in the development of the entire questionnaire-survey based on ISO/IEC 33020:2019 (Peneva, 2021).

- *Analysis and Evaluation of the Current State*

During the consultations held with the management and leading specialists of the enterprise, the presented in Fig. 1 technologies/directions of Industry 4.0 have been discussed and a decision was made on those of them that are applicable to the factory and on which further assessment of the maturity level would be made in order to define the readiness for I 4.0.

These directions are:

A) Maintenance;
B) Robotics and Automation;
C) Cyber Security;
D) Production Planning and Control;
E) Human Resources 4.0 (Training 4.0).

After the brainstorming to determine the priority/potential of above directions for increasing the competitiveness of the enterprise and the use of Analytical Hierarchical Process (AHP), the following criteria and sub-criteria were established (adopted by consensus among the specialists from the enterprise):

{1} Size and Structure of the Investment
- {1.1} Size of the Investment;
- {1.2} Return-On-Investment;
- {1.3} Opportunities for Investment (Investors);

{2} Availability of Resources
- {2.1} Specialists;
- {2.2} Machinery and Equipment;
- {2.3} Infrastructure;

{3} Increasing the Competitiveness of the Enterprise
- {3.1} Increasing Flexibility/Agility of the Operating System;
- {3.2} Reducing Production Costs;
- {3.3} Reducing Degree of Discontinuity and Downtime;

Finally, the following priority ranking was obtained:

B) Robotics and Automation	0,302
C) Cyber Security	0,266
E) Human Resources 4.0 (Training 4.0)	0,187
D) Production Planning and Control	0,141
A) Maintenance	0,104

- *Assessing the Organizational Maturity in Five Directions*

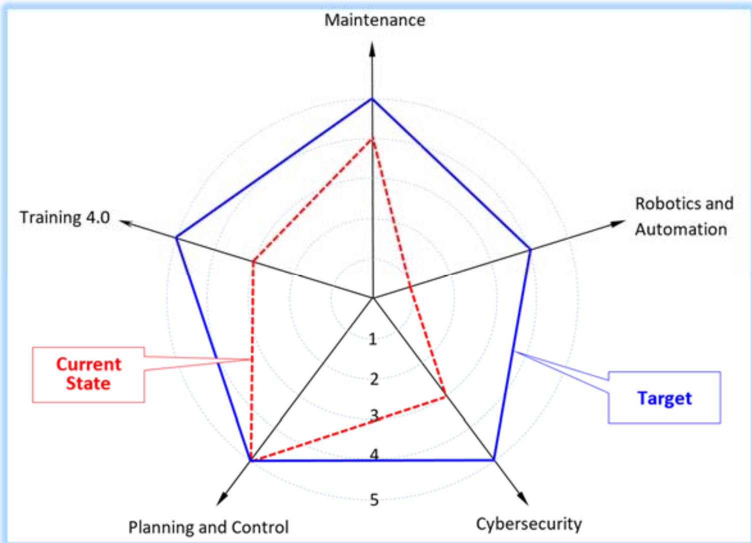
In this step, in accordance with the structure and content of the maturity levels, process attributes and generic practices and the rating scale for the values of the process attributes, an interview was conducted with the management and leading specialists from the enterprise, where the maturity levels were discussed, along with the attributes and practices governing their attainment. The purpose of this interview was to establish the **maturity level reached** (the current state) in relation to the five areas (A ÷ E) defined for Industry 4.0readiness analysis of the enterprise. In addition, alongside the comments on the maturity levels reached, the target values for these levels for each of the **target values** were discussed.

- *Conducting GAP-Analysis*

In this step, a GAP analysis was conducted between the target values for the maturity levels and the currently achieved ones. The values are presented in Table 1 and are shown graphically in Fig. 5.

Direction	Level Reached	Target Level	Gap
A. Maintenance	4	5	***1***
B. Robotics and Automation	1	4	***3***
C. Cybersecurity	3	5	***2***
D. Production Planning and Control	5	5	***0***
E. Human Recourses 4.0 (Training 4.0)	3	5	***2***

Table 1. Достигнати и целеви нива на зрелост спрямо избраните направления

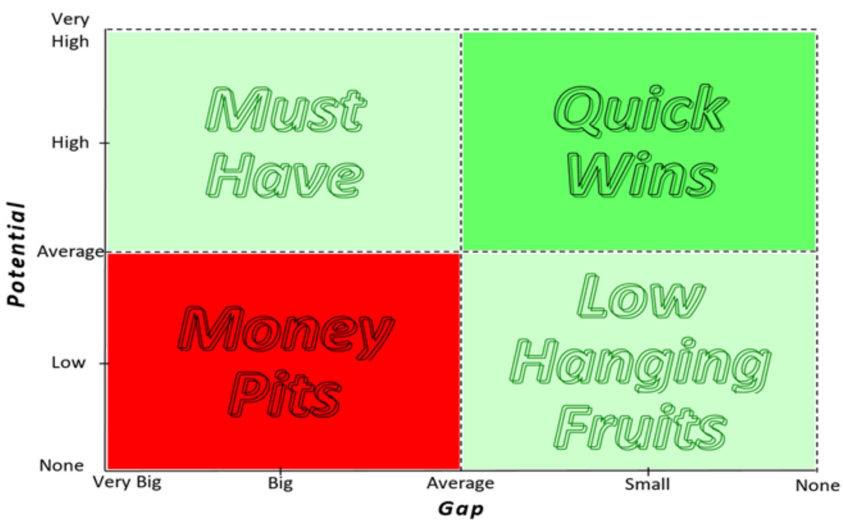


Фиг. 5. GAP-анализ

- *Norm Strategy Matrix*

At the current stage, the Norm Strategy Matrix (Rauch at al., 2020) is used. With its help, Industry 4.0 directions/technologies are selected, which, by their implementation, will ensure the fastest and greatest effect for the enterprise, and therefore – to be the first to be preferred for implementation. The idea of the approach of Rauch at al. (2020) is as follows:

For each of studied I4.0directions, in the coordinate system shown in Fig. 6, on the horizontal axis the deviations ($\boldsymbol{x_i}$) obtained during the GAP analysis are plotted as a difference between the target maturity level for the respective direction and the assessment of the current state.



Фиг. 6. Norm Strategy Matrix (Rauch at al., 2020)

As vertical coordinates, the authors suggest that the values ($\boldsymbol{y_i}$) be determined by an expert assessment of the significance (potential) of the respective trend on a 5-stage Likert scale. The interpretation of the four quadrants of fig. 6 is as follows (Rauch at al., 2020):

Quick Wins – little or no deviation and very high potential. There are opportunities here that should be utilized immediately, and this can be done without special efforts and funding;

Must Have – high deviation and high potential. In this quadrant fall the directions, on the implementation of which the efforts of the enterprise must be directed in order to achieve the necessary competitive advantages;

Low Hanging Fruits – low potential and little or no deviation. The options located in this quadrant, although they are not of great importance for the competitiveness of the enterprise, are anyway "in the hands" of the enterprise and it is obliged to take advantage of them, as far as this contributes to the prosperity of the company without adding significant investments;

Money Pits – the options located in this quadrant have relatively little potential for increasing the company's competitiveness, and it should be further clarified whether it is worth undertaking efforts to overcome such large deviations with the target values, found in GAP analysis. However, this would certainly be on the agenda only after measures to implement the options from the other three quadrants have been identified.

In the current publication, the assessment of the significance/potential of the relevant Industry 4.0 concept/technology/element is not made on the 5-point scale of Likert, but according to the procedure of the AHP method. With it, the highest rank is expressed as a relative share of the whole – that is, it represents a number less than 1 and/or it is expressed as a percentage. Therefore, the Norm Strategy Matrix model (Rauch et al., 2020) is modified as follows:

1) The biggest value on the vertical axis (5) is equated to the highest rank ($\boldsymbol{y_{max}}$) calculated by AHP:

$$y_{max} \cong 5$$

Equation 1 (Peneva, 2021)

2) The values on the vertical axis ($\boldsymbol{y_i^*}$) for the restones are obtained according to the following equation:

$$y_i^* = \frac{y_i}{y_{max}} \cdot 5$$

Equation 2 (Peneva, 2021)

Thus, for the case of the product Cylinder KS-40/22X150-A03-F-M-00, the obtained vertical coordinates are:

A. For Maintenance:

$$y_{\text{А}}^* = \frac{y_{\text{А}}}{y_{max}} \cdot 5 = \frac{0{,}104}{0{,}302} \cdot 5 = 1{,}7$$

B. For Robotics and Automation:

$$y_{\text{Б}}^* = \frac{y_{\text{Б}}}{y_{max}} \cdot 5 = \frac{0{,}302}{0{,}302} \cdot 5 = 5$$

C. For Cyber Security:

$$y_{\text{В}}^* = \frac{y_{\text{В}}}{y_{max}} \cdot 5 = \frac{0{,}266}{0{,}302} \cdot 5 = 4{,}4$$

D. For Production Planning and Control:

$$y_{Г}^{*} = \frac{y_{Г}}{y_{max}} \cdot 5 = \frac{0{,}141}{0{,}302} \cdot 5 = 2{,}3$$

E. For Human Resources 4.0 (Training 4.0)“:

$$y_{Д}^{*} = \frac{y_{Д}}{y_{max}} \cdot 5 = \frac{0{,}187}{0{,}302} \cdot 5 = 3{,}1$$

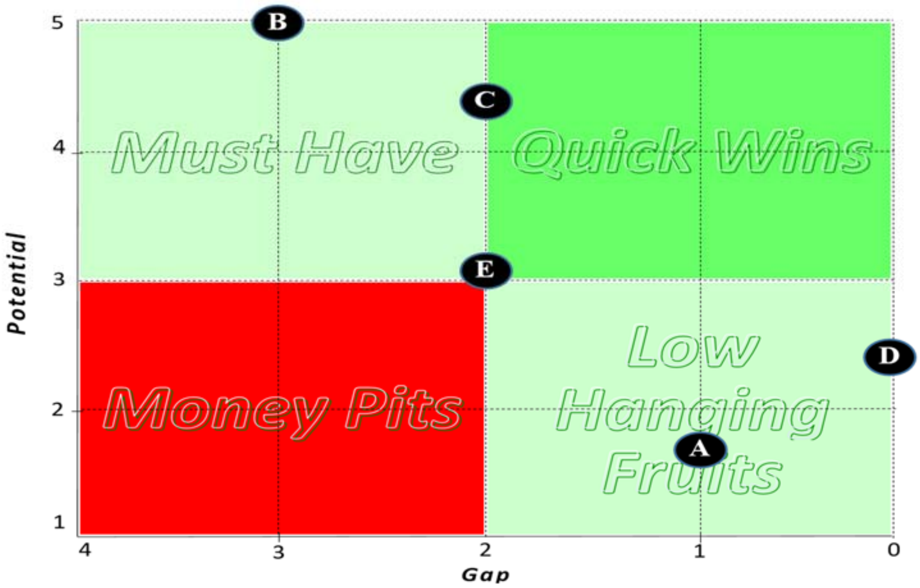
Table 2 presents the above-determined coordinates of the five investigated directions for "Montana Hydraulics", based on which in fig. 7 Norm Strategy Matrix was built.

Direction	Horizontal Coordinate (Gap)	Vertical Coordinate (Potential)
A. Maintenance	***1***	***1,7***
B. Robotics and Automation	***3***	***5***
C. Cybersecurity	***2***	***4,4***
D. Production Planning and Control	***0***	***2,3***
E. Human Recourses 4.0 (Training 4.0)	***2***	***3,1***

Table 2. Coordinates in the Norm Strategy Matrix for Item: Cylinder KS-40/22X150-A03-F-M-00

It follows from the analysis of the strategic matrix of priorities (Fig. 7) that direction **B** (Robotics and automation) has the greatest potential for increasing company's competitiveness, and this is where the management's attention should be directed first (Must Have). Unfortunately, this is where the difference between the target and the actual state is the largest, which implies serious investments. In the long term, however, this decision will bring serious benefits – both financially and in terms of the competitive position of "Montana Hydraulics" Ltd. (quality of products, flexibility and maximum agility of processes.

Next, with no less priority, this time regarding business security, the company's management should take measures to implement projects aimed at reaching the target level for cyber security **C**.



Фиг. 7. Norm Strategy Matrix for Item: Cylinder KS-40/22X150-A03-F-M-00

Although the training of human resources (direction **E**) does not have such a great potential, the so-called "Human capital" is a basic asset for any company and a pledge for the development and increase of its competitive that ability. Direction **E** is on the border between Must Have and Quick Wins and is the next priority in the development plans of Montana Hydraulics Ltd.

As for direction **D** (the ERP system for production planning and control), it is obvious that the enterprise is already cashing in the relevant benefits and advantages that it brings – both in terms of flexibility of the production system and in terms of its effectiveness, and from there – also in terms of financial results. Here, for the future, a strategy should be developed for entering as complete a digitization as possible as a business model and from there – the ever-increasing shaping of "Montana Hydraulics" Ltd. as a modern cyber-physical system – with the specific In this terms big data analytics, integrated systems for monitoring and control in real time and agile production. So the **D** from Low Hanging Fruits will turn into Quick Wins with all the consequent benefits for the enterprise.

Direction **A** (Maintenance) is also in the Low Hanging Fruits area. Things are "most calm" with it –maintenance is at a satisfactory level and is not critical for the moment. However, with a future orientation towards Robotics and Automation, as well as with the transformation of "Montana Hydraulics" Ltd. into an increasingly formed cyber-physical system, the role and potential of direction **A** will significantly increase and it will attract more and more the attention of the company management.

4. Conclusion

In the present publication, aimed at increasing competitiveness of "Montana Hydraulics" Ltd., well-grounded proposals ape made for strategic solutions related to the implementation of concepts and technologies of Industry 4.0, concerning the main production of the enterprise in 5 selected together with management directions on the basis of the conducted research on the maturity level of the enterprise. As a result, the company can take appropriate measures to implement the 5 concepts and technologies discussed.

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