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ASSESSING THE POTENTIAL OF EMERGING DIGITAL TECHNOLOGIES TO TRANSFORM THE PRODUCTION SECTOR

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ABSTRACT: The article proposes an approach to assessing the impact and potential of use of emerging digital technologies in the manufacturing sector, as part of the digitalization process intended to increase the competitiveness of companies. The methodology employed makes use of techniques such as focus groups, TOPSIS (using the HELDA software) and Balanced Scorecard to aggregate online and real-world inputs for achieving a ranking of emerging technologies based on a set of five relevant criteria. The results are then projected for implementation in production companies (especially SMEs) through a series of guidelines and recommendations that managers can act upon.
KEYWORDS: emerging digital technology, production sector, MCDA

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1. INTRODUCTION

In the past decades, the production sector has faced important challenges, in terms of competitiveness and sustainability [1]. The study presented in the current article focuses on assessing the level of adequacy of adopting and implementing emerging digital technologies for small and medium sized companies operating in this field. As this issue is escalating into an existential question with the rise of AI solutions, SMEs are lacking the resources and information that is usually available to their large multinational counterparts, springing up the need to find sensible ways of embracing the new digital instruments without losing their market access, job attractiveness and environmental achievements [2].

Research published in this domain shows that manufacturing companies are usually at a disadvantage compared to other industries, due to their longer product life cycles and the necessity for considerable investment in equipment, personnel and adequate governance systems [3]. Many times, this is compounded by the lack of proper understanding of the potential that digital technologies have in revolutionizing the way their products are being used by customers and the manner in which they can conduct operations [4], [5]. Starting from the current situation, the framework presented below has been designed to provide a possible "shortcut" to more robust and successful business models.

2. RESEARCH METHODOLOGY

The proposed methodology (Figure 1) is divided into four steps that make use of both academic research and good industrial practices to facilitate the transition of production SMEs into a digital future.

The first step is dedicated to identifying the top emerging technologies that impact this domain, based on three distinct sources: common web search, scientific articles search within academic databases and the curated input of two AI GPTs, namely Google's Gemini (2.0 Flash) and Open AI's Chat GPT (GPT-4-turbo). The second step involves defining the relevant assessment criteria for the stated goal of performing an emerging technology adequacy and potential assessment for the sector. In order to ensure an objective perspective, these were defined using an interview process in a small focus group with 6 manufacturing engineers and managers which was then processed based on the researchers' experience.

The emerging technology evaluation constitutes the third step of the approach, and it involves using an MCDA method, namely TOPSIS implemented by the HELDA software [6], to perform the ranking of the technologies based on their correlation with the assessment criteria. The interpretation of the results obtained, and the graphs generated by the software, form the basis for a specific review in the context of production SMEs. Finally, the fourth and final step is dedicated to exploring the possibilities to implement the technologies studied, in the obtained ranked order, with the help of the Balanced Scorecard (BSC). The particularities of bringing these solutions to a manufacturing setting are revealed and guidelines for an improved adoption process are proposed for supporting practical application within companies, taking into account the most relevant stakeholders.

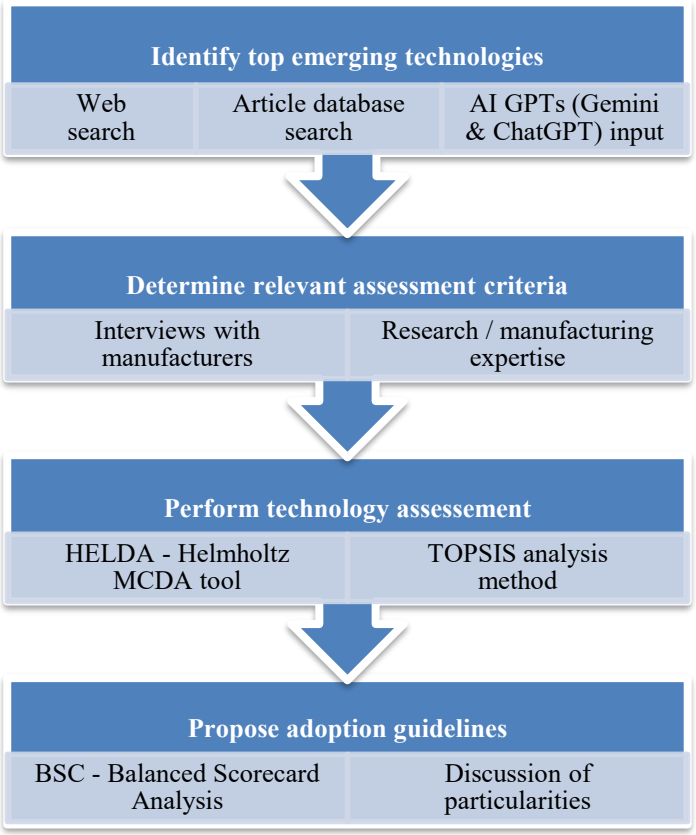


Figure 1. Research methodology for assessing the potential of emerging technologies

3. RESULTS AND DISCUSSION

The assessment was performed using the above-mentioned inputs and the software instrument HELDA, using the TOPSIS outranking method, to ensure clearly (and timeline-based during implementation) stacked results. After performing the intersection of the three information sources described, four emerging technologies have been selected for analysis: AI (for manufacturing), production digital twins, (industrial) Internet of Things and blockchain (for operations). These are considered to be most relevant for the current industry trends and stakeholder requirements.

The interviews with specialists have been used as a basis to establish five initial assessment criteria and their weights on a 1 to 10 integer scale (Figure 2): cost (both CAPEX and OPEX), safety in operation, effectiveness for the business, ease of transitioning the company and stakeholder pressure with respect to the specific technology.

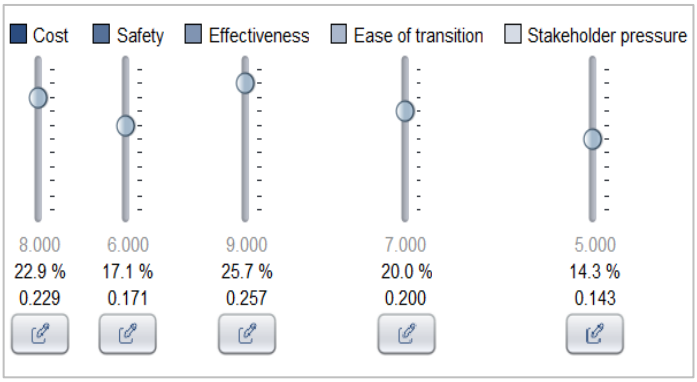


Figure 2. Weights of assessment criteria

(linear scale from 1 - minimum to 10 - maximum importance for manufacturing SMEs, unique values in group)

At the same time, a specific rule was implemented, to have unique values for the ranking criteria and to allow duplicate values for the correlation matrix, which also uses a 1 to 10 scale to record the level of compliance of a certain technology to the determined indicators (Figure 3). In this particular way, it has become easier to engage with the expertise of the specialists as they are used to making difficult differentiation decisions.

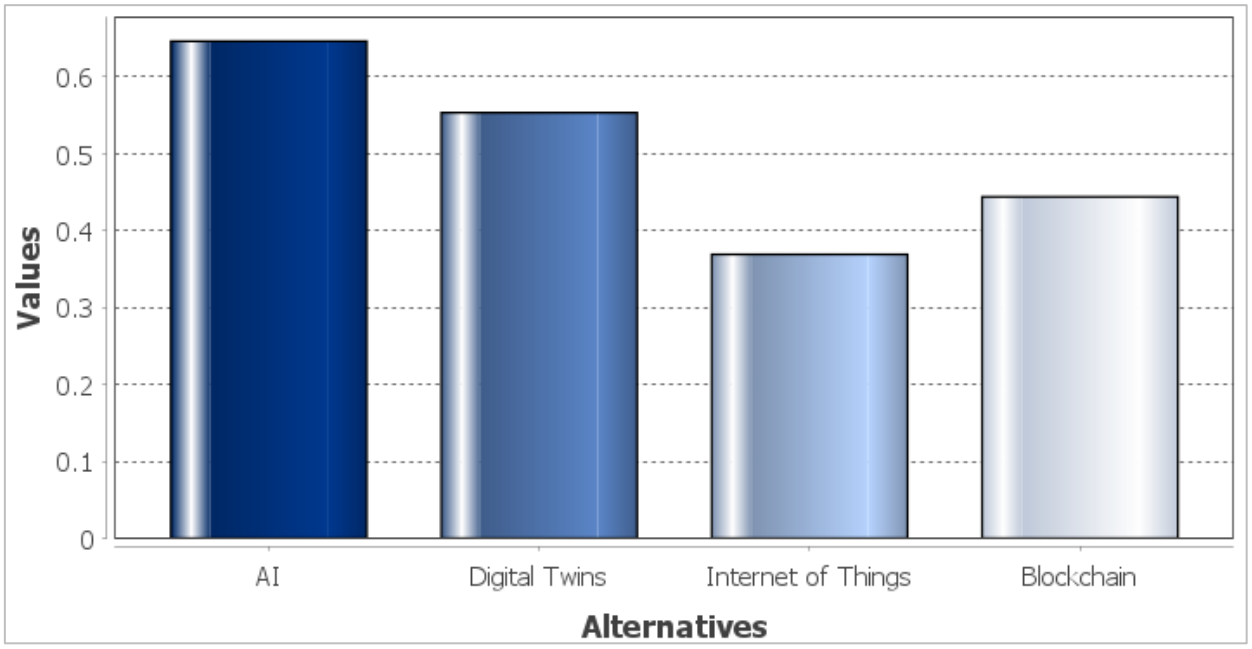
Concerning the outputs of the analysis (Figure 4, a and b), two technologies are leading, AI and Digital Twins, with scores over 50%, while the other two (IoT and Blockchain) rank below this threshold. However, the four domains (and their components) are closely packed in a small range, indicating both their advanced capabilities for manufacturing digitalization and the fact they have not yet reached maturity with respect to production applications.

The hierarchy (a) allows companies to prioritize their investments and to establish a roadmap for digital technology implementation. The numerical results must also be understood in this context as indicators of preference and logical steps in the complex undertakings that company management must commit to. Sequential implementation and observance of criteria fulfillment hold the promise to improve the chances of a successful transition.

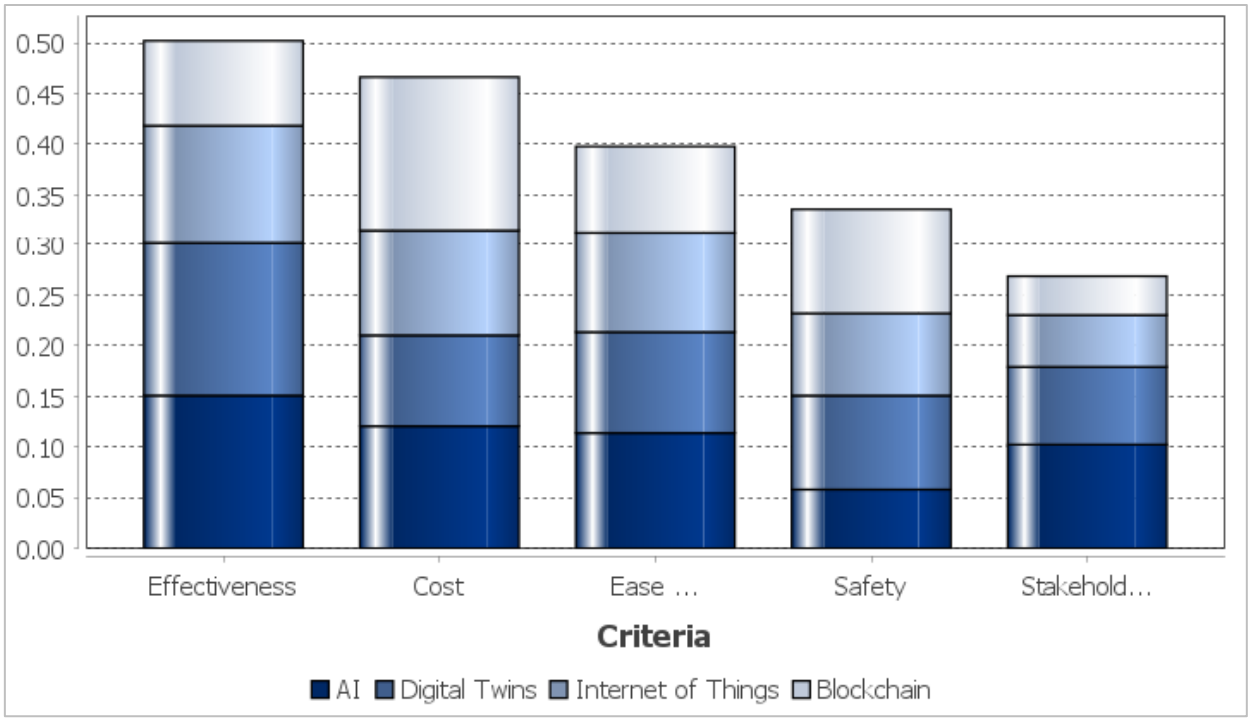
Group/Criterion	Weight	Unit	Prefera...	AI	Digital Twins	Internet of Things	Blockchain
ETA							
Cost	0.229	[]	Lower	7.0	9.0	8.0	5.0
Safety	0.171	[]	Higher	5.0	8.0	7.0	9.0
Effectiveness	0.257	[]	Higher	9.0	9.0	7.0	5.0
Ease of transition	0.2	[]	Higher	8.0	7.0	7.0	6.0
Stakeholder pressu..	0.143	[]	Higher	8.0	6.0	4.0	3.0

Figure 3. Evaluation matrix used to perform emerging technology analysis

(linear scale from 1 - minimum to 10 - maximum contribution to the criteria fulfillment)



(a)



(b)

Figure 4. Ranking (and roadmapping) of emerging digital technologies for the production sector (a) and breakdown of criteria satisfaction based on individual components for a future integrated implementation (b)

The breakdown (b) can further introduce a nuanced digitalization program and with component projects being dynamically interchanged depending on external requirements, internal constraints and available resources. For example, one can observe that Blockchain has a larger contribution to costs while being important for safety, which could prompt the advanced securing of funds, and a possible swap in the timeline with the implementation of IoT, which itself can be folded into the Digital Twins approach.

According to the HELDA analysis, the model has very good stability, with changes to the criteria weights up to 50% not modifying the final top alternative, although the ranking of the other three technologies will vary (Figure 5). It is believed that this comes from the overall business savviness of the interview participants that tended to agree with each other on the criteria and their importance. Effectively, this is establishing a quasi-industry standard for adopting fast-paced emerging technologies.

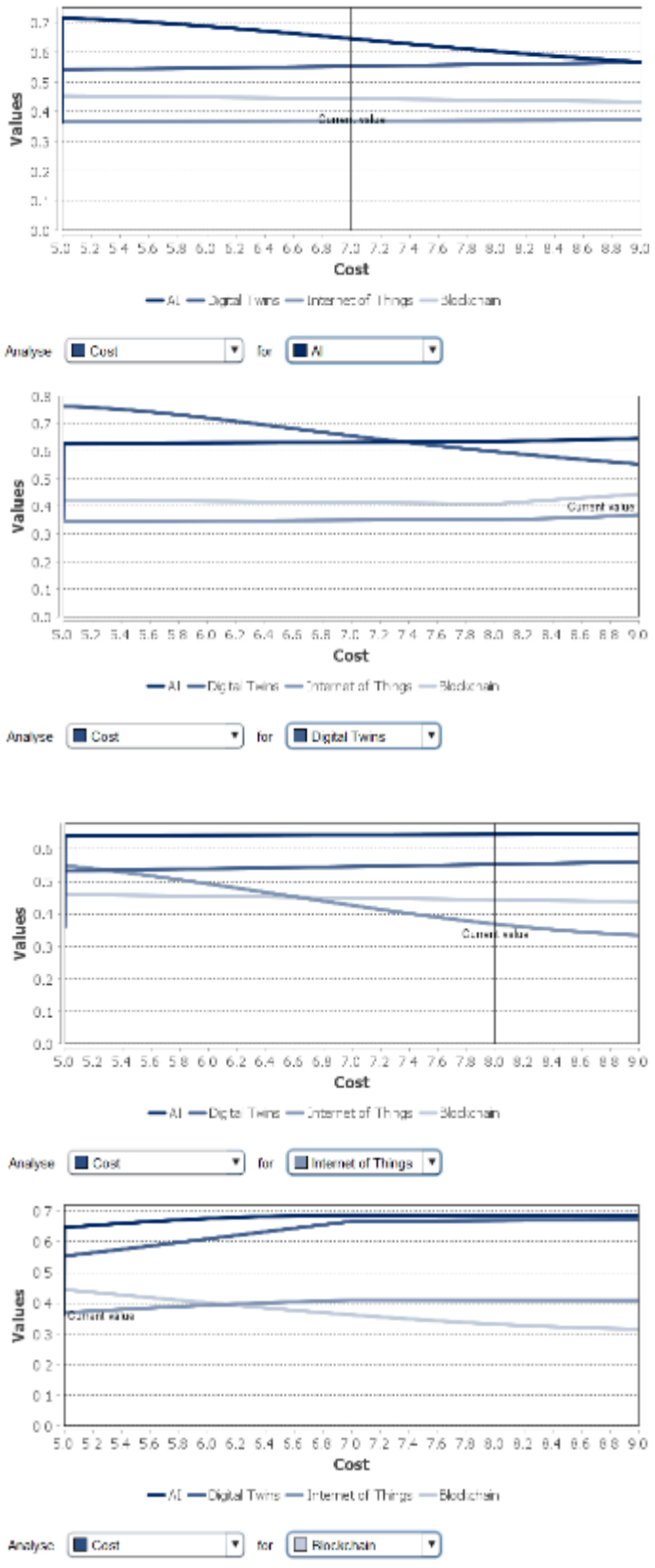


Figure 5. Stability of "cost" across the solutions

Finally, the proposed approach concludes with the application of the Balanced Scorecard method to analyze the strategic options for manufacturing SMEs when choosing the coordinated implementation of emerging technologies. By using its four perspectives, the governance structure can prepare in advance concrete solutions for deployment.

BSC persp.	Implementation protocol
Financial	• An investment plan should be developed over the medium term (3-5 years) • External funding sources can be secured in the form of grants from governmental agencies • Joint ventures with technology providers are possible, as emerging technologies are still looking for industrial validation • Capital expenses are expected to be high, and operational expenses are mostly unknown, so risk management should be thoroughly implemented
Customer	• Customers are only partially aware of the implementation efforts, even if results in terms of enhanced quality, faster delivery and product variety are expected by markets • It is imperative to establish collaborations and data sharing schemes across the entire value chain (suppliers to customers)
Internal business processes	• Activities in this area are very difficult to predict, due to the large diversity of manufacturing settings and processes, but proper planning is essential • The domain is the most important source of competitive advantage if the transition is performed successfully
Learning and growth	• Training of personnel in the use and development of emerging technologies should be done early and often, to keep up with rapid changes • It is possible that the need to abandon an unsuccessful course of action will arise, so flexibility and tolerance of uncertainty are critical for successful deployment • Know-how of the technologies in the manufacturing sector is limited and partnerships with the IT sector and academia is highly recommended

Table 1. BSC analysis for implementation

4. CONCLUSIONS

Based on the analysis performed, it can be inferred that the complexities of adopting emerging digital technologies to manufacturing SMEs and processes stem primarily from two sources: information, awareness and cultural shift on one hand, and financial decision-making on the other hand. The first category is felt strongly by all the stakeholders involved in this industry, while the second category is mostly relegated to the level of company management, although national policies could also contribute to its achievement.

These results are aligned with previous findings of researchers working in different industrial, economic and geographic settings, such as:

- a cross-sectoral study in Turkey that emphasizes the importance of knowledge within the companies concerning the technological solutions [7];
- research performed in the USA that concludes that the size of the organizations and their funding availability influences the process focus of the investment strategy for digital technologies [8];
- an investigation concerning personnel perspectives on using AI in manufacturing in Indian companies which identifies a positive relation between successful deployment of the technology and the level of skill and competence of the employees [9].

Of course, since the Romanian interview group was limited in the current case, it is advisable to extend the research further and revisit the comparisons with other similar reports from all over the world. The topic of emerging technologies is rather recent, and companies will try and test various approaches that will produce a diverse array of results whose investigation can yield scientific insights. Manufacturing organizations can improve their competitiveness and reduces their costs if a coherent and tailored digitalization framework is assumed based on the real needs of the firms.

As the model is refined and generalized, it can be transferred to the public sector in the form of support for the industrial strategies of companies to become more competitive and customer oriented. Also, it can form the conceptual foundation for incentive programs to be undertaken by the various governmental agencies in charge of industrial development.

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