APPLICATION OF THE AHP-TOPSIS-2N METHOD IN PRIORITIZING TECHNOLOGIES OF INTEREST TO THE BRAZILIAN ARMY

ABSTRACT

Technology management includes planning, directing, controlling, and coordinating the development of technological capabilities so that organizations can conceive and achieve their strategic objectives. In the defense area, given the growing dependence between military capabilities and technology, technology management models have been sought to identify and prioritize critical technologies that will guide the strategic planning of an Armed Force. In this context, this article aims at prioritizing critical technologies based on the use of Multi-Criteria Decision-Making (MCDM) combined with the quantitative analysis of patent databases. The MCDM method used was the AHP-TOPSIS-2N, a hybrid approach that brings together the strengths of two established methods, the Analytic Hierarchy Process (AHP) and the Technique for Order Preferences by Similarity to Ideal Solution (TOPSIS), along with two different normalization procedures. As a result, it was possible to prioritize critical technologies of interest to the Brazilian Army for application in medium-term technological development projects (2024-2031).

Keywords: innovation management, systems engineering, operational research, multi-criteria decision-making, AHP-TOPSIS-2N, patent analysis, Brazilian Army.

1. Introduction

Given the growing dependence between military capabilities and technology, technology management models have been sought to optimize processes for obtaining systems and materials for military use. The systematic use of these models in the management of military systems plays a fundamental role in reducing costs and increasing defense capabilities. In this regard, several Armed Forces have periodically prepared lists of critical technologies to prioritize them and make their defense industrial bases more efficient and effective. In line with this good practice, the Brazilian Army periodically lists the technologies of interest that must be developed to increase the Force's operability and technological autonomy.

2. Literature Review

Although several academic works address MCDM or patent analysis as prioritization tools in the context of technology management, the authors are unaware, so far, of any work that has combined MCDM hybrid methods with patent analysis in technology management of defense. In this context, the article addresses the following main themes and references: technological innovation management (Cetindamar et al., 2016; de Weck, 2022), AHP-TOPSIS-2N method (De Souza et al., 2018), patent analysis (Altuntas et al., 2015; Ernst, 1997), and tools used (Bozza et al., 2020; Lens, 2022).

3. Hypotheses/Objectives

To fill the gap identified in the academic literature, the article aims at prioritizing technologies of interest to the Brazilian Army based on the application of a hybrid MCDM method (AHP-TOPSIS-2N) combined with the quantitative analysis of patent databases.

4. Research Design/Methodology

The research methodology is presented in **Appendix A**.

5. Data/Model Analysis

The steps of the method AHP-TOPSIS-2N are detailed in **Appendix C**.

6. Limitations

As a limitation of the research, it is indicated that the prioritization carried out was based only on criteria related to the quantification of how promising the technologies under analysis were, based on data from patent databases.

7. Conclusions

This article aimed to prioritize critical technologies from the use of MCDM combined with the quantitative analysis of patent databases. The MCDM method used was the AHP-TOPSIS-2N, a hybrid approach that brings together the strengths of two established methods, the AHP and the TOPSIS, along with two different normalization procedures.
Therefore, it was possible to prioritize critical technologies of interest to the Brazilian Army for application in medium-term technological development projects (2024-2031), namely: Artificial Intelligence, Extended Reality (Augmented, Virtual and Mixed), Satellite Systems, Cybersecurity, Quantum Computing, Big Data, Sensors and Internet of Things (IoT), and Plasma Electronics. As a result of the identified limitation in Section 6, it is suggested for future work to consider additional criteria that may be useful in the context of defense, such as, for example, strategic alignment and geopolitical issues (technological restrictions, R&D risks etc.).

8. Key References

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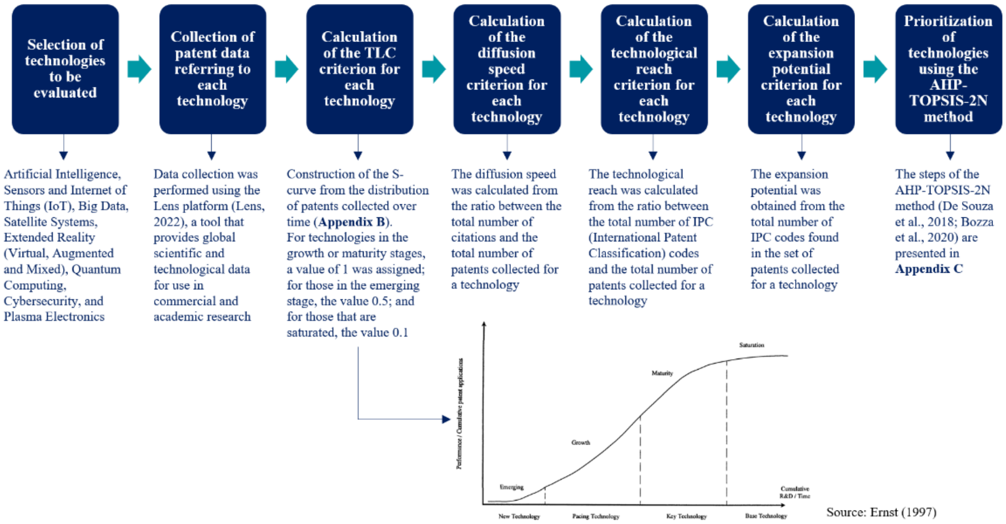
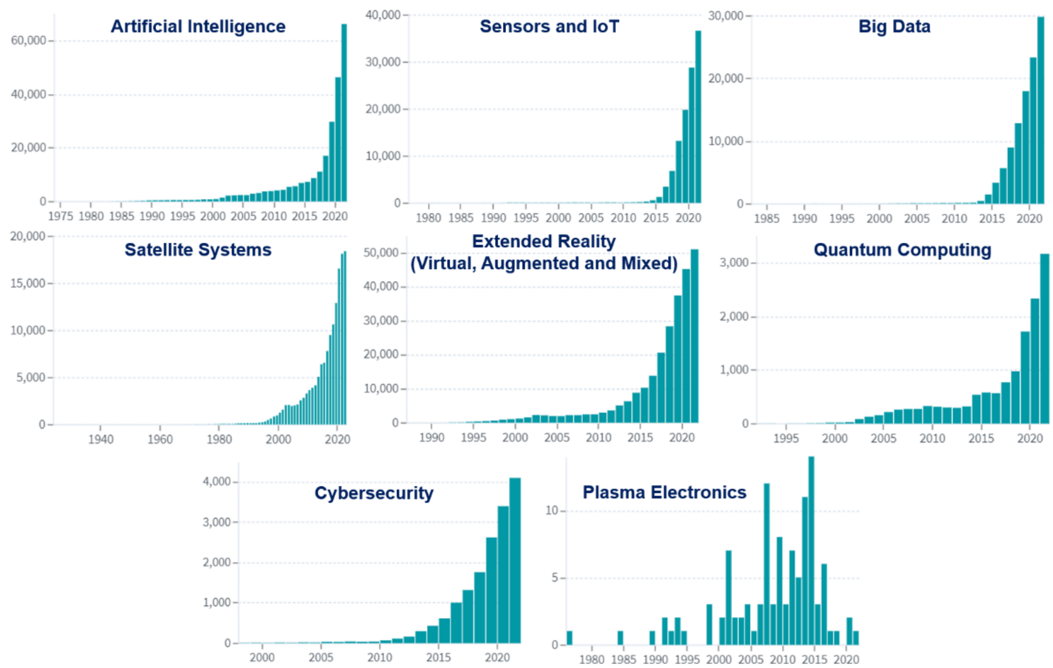
Appendices

Appendix A – Summary of the methodology used in the research



Appendix B – S-curve for each technology



Appendix C – Steps of the AHP-TOPSIS-2N method

1) Establishment of the decision matrix: structuring the score of each alternative concerning each analyzed criterion (**Appendix D**);
2) Preparation of the weighting matrix: using Saaty's fundamental scale, through the pairwise evaluation of each criterion **(Appendix E**);
3) Calculation of criteria weights with the AHP method: by applying the AHP method, the weights of each criterion are obtained. It is important to calculate the Consistency Ratio (CR), which must be less or equal to 0.1 to guarantee the consistency of the analysis (**Appendix E**);
4) Obtaining the normalized decision matrix: in the case of the AHP-TOPSIS-2N method, two different normalizations are used (De Souza et al., 2018) **(1) (2)**:

$$p_{ij} = \frac{x_{ij}}{\sqrt{\left(\sum x_{ij}\right)^2}} \qquad (1)$$

$$p_{ij} = \frac{p_{ij} - minp_{ij}}{maxp_{ij} - minp_{ij}} \qquad (2)$$

5) Construction of the weighted normalized decision matrix: the weighted matrices are obtained by multiplying the weights of the criteria by the normalized matrices;
6) Obtaining the Ideal Positive Solution (A+) and Ideal Negative Solution (A-) (3):

$$A^+ = \{p_1^+, p_2^+, \dots, p_m^+\}; \quad A^- = \{p_1^-, p_2^-, \dots, p_m^-\} \qquad (3)$$

7) Calculation of the Euclidean distances of each of the alternatives in relation to IPS (D_i^+) and INS (D_i^-) (4) (5):

$$D_i^+ = \sqrt{\sum_{j=1}^{n} \left(p_{ij} - p_j^+\right)^2} \qquad (4) \qquad\qquad D_i^- = \sqrt{\sum_{j=1}^{n} \left(p_{ij} - p_j^-\right)^2} \qquad (5)$$

8) Calculation of relative proximity to the ideal solution (6):

$$C_i^+ = \frac{D_i^-}{D_i^+ - D_i^-} \qquad (6)$$

9) Sorting of preferences: based on their proximity to the ideal solution, the alternatives under analysis are sorted (**Appendix F**).

Appendix D – Decision matrix

Technology	TLC	Total of patents	Total of citations	Total of IPC codes	Diffusion speed	Technological reach	Expansion potential
Artificial Intelligence	1	239.316	3.017.098	126.207	12,607	0,527	126.207
Sensors and IoT	1	111.172	470.923	54.715	4,236	0,492	54.715
Big Data	1	103.892	408.566	73.351	3,933	0,706	73.351
Satellite Systems	1	148.687	1.839.099	59.947	12,369	0,403	59.947
Extended Reality	1	253.820	2.919.831	111.169	11,504	0,438	111.169
Quantum Computing	1	13.501	125.954	5.465	9,329	0,405	5.465
Cybersecurity	1	15.947	160.748	6.465	10,080	0,405	6.465
Plasma Eletronics	0,1	109	961	44	8,817	0,404	44

Appendix E – Matrix of pairwise comparisons (AHP)

CRITERIA	TLC	Speed	Reach	Potential
TLC	1	2	3	3
Speed	½	1	2	2
Reach	1/3	½	1	1
Potential	1/3	½	1	1

→

CRITERIA	WEIGHT
TLC	0,455
Diffusion speed	0,263
Technological reach	0,141
Expansion potential	0,141
TOTAL	1

Appendix F – Ranking of technologies by the two normalization procedures

Normalization procedure 1

Alternative	Score
AI	0.9142
XR	0.8565
Satellite	0.7618
Big Data	0.6445
Cybersecurity	0.6404
Quantum	0.6301
IoT	0.6204
Plasma	0.2033

Normalization procedure 2

Alternative	Score
AI	0.8677
XR	0.8010
Satellite	0.7672
Cybersecurity	0.7021
Quantum	0.6885
Big Data	0.6418
IoT	0.6185
Plasma	0.2252